Exploring the Current State of Grades 4 to 8 Science Education in Ontario

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Abstract

This study sought to explore the current state of Grades 4 to 8 science education in Ontario from the perspective of Junior/Intermediate (J/I) teachers. The study's methodology was a sequential 2-phased mixed methods explanatory design denoted as QUAN (qual) → qual. Data were collected from an online survey and follow-up interviews. J/I teachers (N = 219) from 48 school boards in Ontario completed a survey that collected both quantitative and qualitative data. Interviewees were selected from the survey participant population (n = 6) to represent a range of teaching strategies, attitudes toward teaching science, and years of experience. Survey and interview questions inquired about teacher attitudes toward teaching science, academic and professional experiences, teaching strategies, support resources, and instructional time allotments. Quantitative data analyses involved the descriptive statistics and chi-square tests. Qualitative data was coded inductively and deductively. Academic background in science was found to significantly influence teachers' reported level of capability to teach science. The undergraduate degrees held by J/I science teachers were found to significantly influence their reported levels of capability to teach science. Participants identified a lack of time allocated for science instruction and inadequate equipment and facilities as major limitations on science instruction. Science in schools was reported to be of a "second-tiered" value to language and mathematics. Implications of this study include improving undergraduate and preservice experiences of elementary teachers by supporting their science content knowledge and pedagogical content knowledge.

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CHAPTER ONE: OVERVIEW

Science education offers opportunities for discovery, potential for developing curiosity, and a window into the workings of the world around us. Throughout my educational career there were several science teachers who inspired my curiosity for science as a student. These teachers had a passion for science that was evident through the way they taught and lived their lives. It was because of these teachers that I learned to look at the world around me through a critical lens and to ask meaningful questions. I searched for answers that would explain the function of the systems around me; and it was through science that I discovered my unceasing sense of wonder. To reach the edge of human understanding, or even one's own understanding, is a catalyst for curiosity that can fuel active and applicable learning. Acknowledging the impact that these teachers have had on my life has led me to the teaching profession in hopes that I can do the same for others. It is through the subject of science that I hope to use students' natural curiosity to cultivate the intrinsic motivation for learning within my own students. I believe that a life nourished through learning is a life that, invariably, has the potential to thrive.

Combining my experience with science education as an elementary and secondary student with my experience in the Concurrent Teacher Education program (2008–2013) at Brock University, I have come to recognize that there is a huge range in the way students in Ontario are engaging with science. As I reflected on my elementary years prior to Grade 7, I came to realize that I have no specific memories of science class, though lessons and activities from other subjects easily come to mind. When I reached the intermediate grade range, I learned to develop the skill of rote memorization and consequently it was through science that I began to earn some of my highest marks. I began to love science, but for all the wrong reasons. I successfully spent these years learning about science through textbooks and handouts. Without questioning this method of instruction, I did not realize that the information that I was gaining was not applicable to my life and would, as a result, soon be forgotten.

It was not until high school that I was offered authentic opportunities to explore science, its concepts, vocabularies, methods, and natures that my learning in science became motivated by my own interests. I was able to experience science as it applied to my life in a meaningful way. The science content knowledge that I gained in school gave me insight into the seasonal changes I observed throughout the year, the interactions of living organisms around me, and the functions of various mechanical systems that were common to my life. These understandings seemed to relate to my life with greater purpose than the concepts I was learning in the other subjects. The many positive experiences I gained through science allowed me to recognize my interest in science and the limitless possibilities that it holds. Science was often the highlight in my academic schedule; and it was ultimately because of several teachers that I was fortunate to recognize that learning science was a passion of mine. These teachers demonstrated a strong interest in science themselves and helped me to become captivated by the science around me.

Throughout my Concurrent program I was able to observe numerous Junior/Intermediate (J/I) teachers teach science. I also had the opportunity to teach science at the J/I level in several classrooms. Additionally, I worked as a science instructor at Youth University at Brock University for three summers. This opportunity allowed me to engage Grades 4 to 8 students from across southern Ontario with science in various laboratory settings at the university. While continuously reflecting on these experiences I noticed a broad range in general understanding of basic science concepts, inquiry and investigation skills, and desire to participate and engage in science-related activities. I also noticed that the teachers' attitudes toward science vary, with the majority observing from a distance while others participated alongside their students. My experiences in classrooms and as a science instructor have led me to believe that there are inconsistencies in teachers' attitudes and teaching approaches that are influencing elementary science education across Ontario. These experiences have also helped me to recognize that many teachers are experiencing confusion surrounding science pedagogical content knowledge (PCK). Specifically, many teachers seem to be at a loss with how to use science to foster 21st century skills including problem solving, critical thinking, and innovation.

According to several American studies, there are many teachers who feel unprepared to teach science as it is considered to be a "content-heavy" subject (Bulunuz, Jarrett, & Martin-Hansen, 2012; Morrison, 2013). Though science is often regarded as a challenging subject to teach, it is necessary that students be provided with a learning environment appropriate for developing higher order thinking skills necessary for 21st century citizens. These skills include communication, problem solving, innovation, critical thinking, analyzing, and evaluating (Madhuir, Kantamreddi, & Goteti, 2012). Science is one of several subjects that can provide a learning environment to nurture these types of skills. To be successful in the 21st century, students need both knowledge and skills from within the scientific and technological fields. I believe that as Canadians, we want and should expect our students to be globally competitive in a society that is ever-dependent on science and technology. In order to make this happen, however, teachers need to be adequately prepared to teach science and they need to have access to the necessary resources in order to effectively engage students with science to foster these necessary skills.

The purpose of this research was to perform a two phased mixed-methods study to explore the current state of Grades 4 to 8 science education in Ontario schools. This was achieved by gathering data about teacher attitudes, teachers' academic backgrounds, teaching practices, available resources, and scheduled time allotment for science instruction from the perspective of J/I teachers. Participants can be described as J/I teachers who teach science to students in Grades 4 through 8 in Ontario. Data were collected through an online survey and follow-up interviews with purposefully selected participants. This information has provided insight into the various ways that science is being taught in Ontario and the underlying factors that are influencing our students' opportunities to effectively engage with science in schools.

Statement of Problem Context

Recognizing a need for students to become more engaged with science is not a modern dilemma. In 1951, James B. Conant, an American chemistry professor from Harvard, described his "bewilderment of laymen" with regard to the public's general understanding of science and the possibilities that it offers (as cited in Next Generation Science Standards [NGSS], 2013, p. 3). This is consistent with contemporary science education researchers such as Hodson (2003), who states that we need to take action on the science curriculum as it does not support the academic needs, interests, or ambitions of 21st century students. Scientific advancements continue to improve the quality of life we experience, yet a general state of scientific illiteracy endures throughout global, provincial, and local arenas.

Global

Scientists and science teachers alike believe that scientific exploration aims to explain the workings of both natural and human-made systems in our world. It is important to note that while science can be seen as an organized structure of current theories and concepts, it is also recognized as a set of practices and a historical collection of information (NGSS, 2013). Governments worldwide attest to rich science education programs contributing to active citizen engagement in the fields of science, technology, engineering, and mathematics (STEM) (Minner, Levy, & Century, 2010). Twenty-first century students require an understanding of science and technology as it relates to their lives and the lives of future generations in order to participate in society as informed and engaged citizens. If students do not learn about the process of science in the real world and do not come to know about science-related job opportunities, they will be less likely to seek involvement in these arenas (Let's Talk Science, 2013).

The *Learn Canada 2020* document states that, "All children in our elementary to high school systems deserve teaching and learning opportunities that are inclusive and that provide them with world-class skills in literacy, numeracy, and science" (Council of Ministers of Education, Canada [CMEC], 2008, p. 1). Global assessments (e.g., *Programme for International Student Assessment* (PISA)) indicate that young Canadian students demonstrate a comparatively high aptitude for science; however, approximately two-thirds of these students choose not to enroll in science classes after Grade 10 once they have met the minimal requirements for high school graduation (Let's Talk Science, 2012). This high aptitude for science may indicate that our students have great potential to succeed in science-related careers. Effort to encourage more students to engage in science education could result in benefits to these individuals and society at large.

Ontario

According to the 2013 Let's Talk Science Report, Ontario is entering a future of "people without jobs and jobs without people" (p. 16). This same report proposes that an estimated $24.3 billion in economic activity has been lost in Ontario due to employers being unable to hire people with the necessary STEM skills such as innovation, problem solving, creativity, and data analysis (Let's Talk Science, 2013). In 2010, an Ipsos-Reid study was commissioned to gain insight into the attitudes of Ontario students toward science. The results from this study indicate that as students get older they begin to view the subject of science as involving difficult and complicated subject matter. Many students abandon the idea of seeking STEM-related careers as they fail to recognize the relevance of science education to the real world (Let's Talk Science, 2010).

The three primary goals of science education, according to the Ontario Ministry of Education (2007a) are: (i) to relate science and technology to society and the environment; (ii) to develop the skills, strategies, and habits of mind required for scientific inquiry and technological problem solving; and (iii) to understand the basic concepts of science and technology (p. 3). Additionally, scientific and technological literacy is recognized as the "overarching objective" of science and technology education (Ontario Ministry of Education, 2007a, p. 3). There are many definitions for scientific literacy though it is commonly regarded as the ability to understand how science is conducted in the real world and how this work influences the relationship between society and the environment (Hodson, 2011; NGSS, 2013; Ontario Ministry of Education, 2007a). Additionally, the Science Co-ordinators' and Consultants' Association of Ontario (SCCAO) and Science Teachers' Association of Ontario (STAO/APSO) *Position Paper: The Nature of Science* (2006) adds that a scientifically literate person has the ability to read, comprehend, and critically evaluate media reports about science, and is able to confidently participate in discussions and decision-making activities that involve science. Achieving this level of scientific literacy can only be a realistic goal for science education if the teachers who are to instill these skills and level of understanding in their students have the particular skillset and foundational knowledge to do so. One primary challenge with this aim at the elementary level is that, as of 2012, only 8.7% of J/I teachers held the Ontario College of Teachers' certification to teach science (Ontario College of Teachers [OCT], 2013b). This statistic may suggest that very few teachers have foundational scientific knowledge and may not be scientifically literate themselves. J/I teachers are required to hold a qualification (teachable) for only one specific curricular subject. Additionally, principals in Ontario hold the right to assign the teaching of curricular subjects to teachers despite their specific qualifications. These systemic issues may underpin the reality of this low statistic and the resulting limited focus on science in education.

An American study conducted by Bulunuz and Jarrett (2010) accounts that middle school teachers report feeling the least confident teaching science among all subjects. It would be reasonable to extrapolate the results from this study to the Ontario context. By recognizing the high number of teachers not specifically qualified to teach science in Ontario, it is disconcerting to consider what this might mean for science education at large. For teachers having to teach science, feelings of uncertainty may be symptomatic of an overall weakness in teacher education programs, professional development (PD), or an oversight on the academic foundation required to confidently teach science as it applies to a real-world context. Best practice in science education, according to the National Science Education Standards, involves scaffolded levels of scientific inquiry where inquiry skills are initiated in the early elementary grades (National Research Council [NRC], 1996). In Ontario, Primary/Junior (K-6) teachers are officially generalists, who do not require a background in a teachable subject area, and most likely lack expertise in science education and science-reform strategies. This shortage of background knowledge potentially limits these teachers' ability to support their students' understanding of scientific concepts and would likely impede the facilitation of skill building instructional strategies like scientific inquiry. Elementary students are not only experiencing a curriculum biased by the background knowledge and preferences of their teachers (Harlen, 1997), but they may also be missing out on opportunities to develop the thinking skills and application skills required to initiate self-confidence and foundational interest in science (Fitzgerald, Dawson, & Hackling, 2013). Ultimately, if teachers do not feel confident teaching science it is unlikely that their students will feel confident learning science themselves.

The *Trends in International Mathematics and Science Study* (TIMSS) is an international assessment that collects and analyzes student achievement in science across 63 countries and is facilitated through the *International Association for the Evaluation of Educational Achievement* (International Association for the Evaluation of Educational Achievement, 2014). The TIMSS is one of several external cyclical assessments that evaluate the progress of science education in Ontario (Education Quality and Accountability Office [EQAO], 2014). In Ontario specifically, there is no internal accountability assessment specific to science education, unlike other provinces such as Alberta (Alberta Education, 2015). The results from the most recent TIMSS assessment in 2011 demonstrate that Ontario's elementary science scores have been declining since 2003 (Fazio & Karrow, 2013). These declining scores may suggest that the current strategies being used to facilitate science education in Ontario are not as effective as they should be. Additionally, these declining scores indicate that despite the importance and the possibilities that science education holds for individuals and society, it is not an educational priority, especially when compared to language and mathematics—the subject matter used for annual standardized testing in Ontario (Fazio & Karrow, 2013).

The Ontario Curriculum Grades 1-8: Science and Technology (2007a) document offers many specific expectations that involve skills such as investigating, researching, inquiring, and communicating. However, as with many curriculum documents, there is an emphasis on science content knowledge. Definitions, diagrams, identification charts, and qualitative descriptions can be assessed more objectively, leaving learning outcomes involving skill development out of the equation. The *Science and Technology* curriculum does include standardized inquiry/experimentation inquiry/research continuum charts; however, these charts are to be used for the assessment of learning outcomes for students in Grades 1 through 8 with no indication of standard benchmarks for grade-to-grade progression. Teachers who feel comfortable facilitating scientific inquiry will most likely have to begin at the most basic level if the students' previous teachers did not invest in the development of these skills.

School Districts

A typical J/I science class in Ontario would involve about 25 to 30 students and one teacher. There is no standard time allotment for science instruction mandated by the province; however, the Arts Education Consultants of Ontario (2012) have published a recommendation that science instruction should account for 200 minutes, or between 10–15% of instructional time, in a 5-day cycle. Science can be put on a half-year rotation with another subject, such as social studies, or taught in alternating units of study. Science is sometimes taught on rotary at the J/I level that may allow for more students to receive science instruction from teachers with expertise in science. However, there has recently been a reduction of rotary in Ontario in an effort to increase instructional stability for students (Bluewater District School Board, 2015). As previously mentioned, with finite instructional time, subjects with a higher priority status often dominate instructional timetables, effectively leaving other subjects, like science, to be designated and treated as a second-tiered subjects.

The primary issue that I have observed in a local school district is that many teachers are not only neglecting critical skill development opportunities, like those that can be facilitated through scientific inquiry, but they are avoiding engaging their students in science altogether. Some students are having the opportunity to engage with science in ways that develop their science-related knowledge and skills, while others are not. There are a myriad of reasons for this instructional variation; however, additional programming offered to some students but not others is one example of this discrepancy. Design and Technology programs and science fairs, that many students enjoy and thrive in, are unequally offered and facilitated across schools and school boards. Unequal resource availability, teachers' lack of science content knowledge and related pedagogical strategies, and a shortage of science-related PD are just a few reasons for these inconsistencies.

In terms of instruction, I have observed science being taught solely through independent reading of science textbooks to high-level scientific inquiry units of study. Discussions with teachers about hands-on activities have allowed me to recognize that many believe they are facilitating inquiry practices when their students are simply demonstrating their ability to read and follow prescribed instructions. Unfortunately, even when high-level scientific inquiry is facilitated, if the process and skills have not been scaffolded properly, many students end up feeling lost, frustrated, and unmotivated to work through the learning process. Lastly, I have observed some teachers actively trying to incorporate scientific inquiry activities with little understanding of how to effectively assess this type of student achievement. As a whole, the science instruction that I have witnessed across southern Ontario is not offering enough students the science education that they deserve. While not necessarily consistent, the instructional strategies, available resources, and time allotment for science instruction in Ontario is resulting in insufficient student outcomes, as seen in the results of some large-scale assessments (e.g., TIMSS) (Fazio & Karrow, 2013).

Many of these observations align with current literature that discusses elementary science education; however, much of the research is based in the USA and does not speak to the current state of affairs within Ontario, Canada. Research at the provincial level is required to identify the unique characteristics and circumstances being faced by school districts and teachers. Findings from this research will provide information necessary to identify and implement the supports to improve the quality of elementary science education in Ontario.

Definition of Terms

This section provides the definitions for several terms used throughout the remainder of the thesis. These definitions provide the specific designation or context of each term for this research project. The purpose of defining these terms in this section is to maintain consistency and avoid possible misconceptions of terms that have multiple meanings.

- **Attitude:** A positive or negative predisposition toward something that is influenced by one's level of enjoyment, interest, values, and self-confidence. An attitude helps one to construct a set of priorities that outlines an action agenda (Ernest, 1989; Pajares, 1992; Simpson, Koballa, Oliver, & Crawley, 1994).
- **Elementary:** With regard to the organization of the Ontario Ministry of Education, the term elementary refers to Kindergarten (K) through Grade 8 (Ontario Ministry of Education, 2013a). An elementary school can refer to groups of students from K–Grade 8, K–Grade 5, K–Grade 6, Grades 5–8, and/or Grades 6–8. At a curriculum level, elementary refers to Grades 1 through 8 (Ontario Ministry of Education, 2007a), as Kindergarten has its own curriculum depending on the program offered (Ontario Ministry of Education, 2012).
- **Instructional Strategies:** The processes or techniques that a teacher uses to deliver content material or facilitate skill development in order to enhance student understanding and promote student learning independence (Alberta Education, 2002).

- **Junior/Intermediate (J/I):** Educational grade level divisions: Junior (Grades 4–6), Intermediate (Grades 7–10) (OCT, 2013a). However, for this study, Junior/Intermediate will only refer to Grades 4–8 in order to focus on the elementary context.
- **Pedagogical Content Knowledge (PCK):** A concept that refers to the interpretations and transformations of teachers' content knowledge within the context of teaching or facilitating student learning (van Driel, Verloop, & de Vos, 1998).
- **Scientific Inquiry (SI):** A teaching and learning strategy used to acquire knowledge about natural and human-made systems in the world. Students identify problems and patterns, ask questions, develop explanations, test explanations, compare collected data with current scientific information, and communicate processes and findings (NRC, 2000).
- **Scientific Literacy:** An understanding of the nature of science, or how science is conducted in the real world. This understanding includes knowing about how science research is conducted, how new scientific knowledge is validated, and the cost-benefit analysis involved in applying new knowledge. Scientific literacy also involves an understanding of what scientists, engineers, and technologists do and how their work is interconnected in influencing society and the environment (Hodson, 2011; NRC, 2013; Ontario Ministry of Education, 2007a).

Purpose of the Study

The purpose of this study was to investigate the current state of Grades 4 through 8 science education in Ontario elementary schools through the lens of J/I educators. Data were collected from teachers who currently teach science at the J/I level, recognizing that not all J/I teachers are assigned to teach science.

The objectives of this research project included: (i) determining the attitudes that practicing J/I science teachers have toward teaching science as a subject; (ii) gaining insight into the teaching strategies currently used by practicing J/I science teachers; (iii) developing an understanding of the academic and professional science-related experiences that practicing J/I science teachers have had to assist them in developing their science instructional strategies; and (iv) identifying the available resources and time allotment for science education at the Grade 4 to 8 level across Ontario.

One of the anticipated outcomes from this study was to gauge the emphasis and importance currently placed on science education in Ontario. Collected data were expected to indicate the attitudes that practicing J/I science teachers bring to their classrooms and the confidence that these teachers have to engage their students in science as a subject in school. Acknowledging the strategy of scientific inquiry as a best practice within science education sets a standard to which the implemented strategies reported through the survey and interviews were compared. Understanding J/I teachers' science-related background experiences provides an indication of the portion of J/I teachers who are able to utilize their own scientific literacy to enhance science instruction for their students. Finally, being aware of the resources available and the time allotted for science instruction in schools allowed for a greater understanding of the improvements that can be made to assist J/I teachers in the facilitation of science instruction.

Research Questions

This study addressed the following research questions. These questions were developed to elicit data regarding the current state of science education at the Grade 4 to 8 level in Ontario, Canada, from the perspective of J/I teachers. The research questions that guided this study were:

- What attitudes do J/I teachers have toward teaching science?
- What science-related academic and professional experiences do J/I science teachers have?
- What teaching strategies are J/I teachers currently using to teach science?
- What support resources are available to teach science in elementary schools?
- How much instructional time is allocated for science in elementary schools?

These questions prompted the collection of data to explore the main aspects of elementary science education in Ontario. These main aspects included J/I science teachers' attitudes, background experiences, pedagogies, resource availability and use, and instructional time allotment. All survey and interview questions stemmed from these five research questions.

The influence of science-related background experiences on the attitudes and teaching strategies employed by J/I science teachers were assessed using survey and interview data. Survey participants and interviewees were asked to identify the resources available to them and the time allotted for them to teach science. Interviewees were also asked to suggest areas for improvement within elementary science education. Lastly, participants' insights as to what might constitute effective reform of science curriculum documents and policy was solicited. With a greater understanding of the current state of

Grades 4 to 8 science education in Ontario we can hope to initiate improvements that will result in providing more elementary students with the educational opportunities and experiences that promote scientific literacy and foster global citizens who see potential for themselves in science communities.

Conceptual Perspectives

Teaching elementary science in an effective manner is a highly complex task. The need for content knowledge, an understanding of and experience with reform-based science teaching practices, availability of resources and time, and the priorities of educational policy makers all play an influential role on the success of science education. The expectations held by society for elementary science teachers continue to be high despite the fact that most of these educators are certified as generalists (Kirik, 2013). With a limited resource pool of elementary teachers educated specifically to teach science, students across the province are receiving a wide range of experiences and opportunities that may be limiting them academically and/or from future involvement in science-based careers.

Elementary science education plays a significant role in students' perception of science as it relates to the real world and how likely it is that they will pursue science beyond mandatory educational requirements (Bressler & Bodzin, 2013; Fitzgerald et al., 2013). Supporting the understanding of and the engagement with scientific practices increases students' level of preparedness for science-related academic and workplace opportunities. Recognizing that our students will need to fill the increasing number of science-related jobs highlights the connection between science education with social and economic realms. In order to maintain a current and competitive approach to science education, our provincial government must actively review and develop curricula and supportive measures to ensure that both students and society benefit from the desired expectations and outcomes.

Reform is particularly difficult in elementary science education due to the fact that most teachers lack the appropriate science background often required to facilitate an accurate and effective curriculum, let alone advocate for change (Nowicki, Sullivan-Watts, Shim, Young, & Pockalny, 2013). Current American science education reform documents suggest that scientific inquiry practices should be a primary teaching strategy used to support students' construction of scientific concepts and skills (NRC, 2013). The beliefs that J/I science teachers hold about teaching science may align with reform concepts; however, there is often a gap between belief systems and practice (Capps & Crawford, 2013). This gap is often referred to as a rhetoric-practice gap. By analyzing teachers' attitudes toward teaching science, their knowledge of reform-based science practices, and their science-related background experiences with the instructional strategies they implement, a deeper understanding of the current state of affairs within science education in Ontario can be developed.

Importance of the Study

Few debate the need to re-evaluate the current practice of science education. Undoubtedly, the relevance and value of science is largely dependent on available contemporary knowledge. Very little research has been conducted within Ontario regarding the current state of science education. Ontario, as a province, has no assessment for K–12 science, thus leaving the Ontario Ministry of Education to rely on external assessments, such as *Pan-Canadian Assessment Program* (PCAP), *Programme for*

International Student Assessment (PISA), and *Trends in International Mathematics and Science Study* (TIMSS) to provide information on student achievement within science. A limitation of relying on these external assessments, however, is that they are not geared specifically to assess student achievement within the Ontario context.

At this time, when the global economy and the job market are evolving rapidly, we must consciously consider whether our youth will be prepared with the skills to thrive. Though Canada is considered to have a top-tiered education system, complacency within science education will undeniably leave us behind as other countries actively refine their STEM-based talent (Let's Talk Science, 2013). Human Resources and Skills Development Canada, in its most recent 10-year employment growth outlook, reported that the majority of growth will take place in the STEM fields and that as much as 75% of this growth will be in high-skilled occupations (Employment and Social Development Canada, 2014). This number can only be expected to increase as our knowledge-based economy continues to advance. Our focus needs to be on developing an education system that supports future generations with the necessary skills to fill employment gaps for our nation, and, more importantly, to set our students up for a high quality of life. The 2012 Let's Talk Science report *Spotlight on Science Learning: A Benchmark of Canadian Talent* states:

> As a nation, we need to grasp the current state of science learning, understand the full scope of its relevance, discuss whether we're supporting science learning sufficiently and develop innovative ways to generate even more interest in science among Canada's youth. (p. 5)

We can grasp the current quality of science education and begin to understand specific areas for improvement through an analysis of science teachers and science teaching.

This research is important for teachers, teacher education departments, Ministry officials, politicians, educational researchers, and educationally focused professional associations (i.e., STAO) as its purpose was to explore the current state of Grades 4 to 8 science education in Ontario and identify areas for improvement. Students who receive an enriching science education will have the opportunity to develop higher-order thinking skills like critical thinking, problem solving, and data analysis that have cross-curricular and career benefits (Bloom, 2006). Students who are not receiving this type of education are currently at a disadvantage and they will continue to be if the necessary changes are not made.

The results from this research provided a thorough representation of the attitudes that practicing J/I science teachers have toward teaching science, their science-related academic and professional qualifications, teaching strategies currently being used in science classrooms, and the resource and time availability for science instruction. Survey results and interviews helped to inform the recommendations for future curriculum and policy reform as well as to provide suggestions for improved science-related PD opportunities for elementary teachers.

Scope and Limitations of the Study

There were several limitations to be considered while conducting broad-scale research through survey analysis. Considering population distribution across Ontario, it was expected that the data collected would originate from the Greater Toronto Area (GTA) and/or other densely populated regions in Ontario. This reality may have caused the data to be slightly more representative of areas with higher populations than areas with lower populations, assuming that the characteristics of science education vary from region to region. While there are no studies specific to Ontario that suggest a variation in educational characteristics across regions, several American studies do indicate a difference in educational qualities between rural and urban regions. These studies suggest that rural students in lower socioeconomic areas are typically at a disadvantage with fewer extracurricular opportunities that support science, instructional resources, and funding to support science instruction (Avery, 2013; Lee & Krajcik, 2012; Smith, Nelson, Trygstad, & Banilower, 2013).

The first round of data collection was conducted through an online survey that was posted on several educational teacher forums. Casting a wide net typically allows for a large data set to be collected; however, the population most likely to select themselves to participate in this survey would include those who are active in these online communities, those who see science education as a priority, and those who are motivated to look for resources and support to benefit their science instruction. Therefore, participants may primarily represent a population of J/I teachers who are already committed to science education rather than J/I educators who teach science, but may have less of an interest in the subject area.

The second round of data collection was conducted through follow-up interviews. The researcher selected interviewees who reported a maximum variation of science instructional strategies and resource use, confidence with teaching science, and years of experience. This sampling was contingent upon the participants satisfactorily completing the initial survey and indicating willingness to participate in the second stage of research.

To an even greater degree than the survey, the majority of the participants who volunteered for an interview were expected to have a positive attitude toward science. A teacher who feels confident teaching science would be more likely to volunteer to participate in the interview process. This was expected to potentially limit the data collection with respect to teachers who have poor attitudes toward science.

Outline of the Remainder of the Document

Chapter 2 of this document will provide a summary of the literature relevant to the current practices of elementary science education, current best practices in science education, the results of global science education assessments, and the necessary benefits of science education for our scientifically advancing society. The literature review will touch upon the current national and provincial science curriculum documents. It will also present a collation of research on the preparedness of elementary science teachers to teach science with the high expectations set before them, and how students are currently responding to the science instruction they are receiving.

Chapter 3 will provide a detailed description of the methodology and procedures that were followed for the completion of this study. The choice of a mixed-methods research design is justified. The process of survey distribution is described. Data collection and analysis methods are explained; in addition, the steps that were taken to ensure the reliability and validity of the findings are described. The ethical considerations for this study are presented followed by the limitations to this study.

Chapter 4 provides a brief description of the design of this study. The research questions that guided the study are provided. The findings from the study are provided in an integrated fashion based on themes related to the research questions.

Chapter 5 discusses the importance of the findings in relation to the guiding research questions and to the current literature. The implications of these findings are discussed in terms of practice and future research. Lastly, recommendations for curriculum and policy reform are made.

CHAPTER TWO: LITERATURE REVIEW

Science education has found its way to the forefront of many educational, political, environmental, and economic debates. Among continuous scientific and technological advancements, science education continues to hold the responsibility of both preparing scientists and engineers for our nation's workforce and equipping the general population with basic scientific literacy. As it stands, science in schools is not meeting the needs of students, nor is it geared to the interests or aspirations of young citizens who will inherit the responsibility of living within and preserving a world plagued by increasingly complex challenges (Hodson, 2003). The global economy, the natural environment, as well as educational policies of the 21st century have created both high-order challenges and distinct opportunities for teaching and learning science (McFarlane, 2013). The science curriculum needs to be relevant and applicable so that upcoming generations are scientifically and technologically literate (Hodson, 2003; McFarlane, 2012). The focus on science education needs to begin in elementary schools. To make this happen, those who teach science need to be adequately prepared to fulfill the responsibility of fostering these literacies in their students.

This chapter begins by outlining the importance of elementary science education in response to our society's increasing dependence on scientific and technological advancements. A discussion about scientific literacy follows, providing an outline of the overarching goal for science education. Next, the national and international assessments that assess student achievement in science within Ontario are outlined. The importance of teacher attitudes, PCK, teacher self-efficacy, and the effect of teachers' background experiences on these psychological constructs are also discussed. This is followed by a description of some of the current challenges with elementary science education. Lastly, several science-based reform teaching strategies are discussed.

Elementary Science Education

Science is a dynamic and innovative process that allows us to seek and develop a greater understanding of the interconnected systems within our environments (STAO/APSO, 2006). The growing insight that science provides allows us to make more informed decisions about important issues such as health, the environment, sustainable energy sources, technological advancements, and bioengineering, to name a few. According to the 2007 *Science and Technology* curriculum, the primary goal of science education is to develop individuals who are scientifically and technologically literate, who in turn possess the knowledge, skills, and mindset required to actively participate in a world that is increasingly dependent on science and technology. In order for the goal of scientific and technological literacy to be attained, the current effort being invested into elementary science education needs to be evaluated.

Formal education will not fully prepare students for life's numerous challenges; however, having the opportunity to experience a learning environment that develops critical thinking, literacy, numeracy, communication, and analytic skills can lead to a strong foundation for lifelong learning (Let's Talk Science, 2013). Current literature indicates that student interest in science declines with age. This is possibly the cause for only about half of our Canadian high school graduates earning a Grade 11 or 12 mathematics or science credit (Let's Talk Science, 2012). Classroom science can act as a starting point for developing these transferable skills. Using a cross-curricular teaching model not only highlights the fact that science influences every aspect of our lives, but it also facilitates a multiperspective approach where student interests can be incorporated (Bloom, 2006). Unfortunately, the many students who do not complete science courses in high school end up missing out on further educational opportunities and/or science-related employment (Let's Talk Science, 2013).

Young citizens need to develop both the knowledge and skills that will be required of them among the increasingly complex environmental, health, political, and societal challenges that they will face. In order to foster this knowledge and these skills the science curriculum needs to encourage applicable learning tasks that enable the development of creativity, innovation, and problem-solving strategies (Bok, 2006). Processes of exploration, discovery, and problem based learning, often facilitated through scientific inquiry, should be among the primary qualities of all science instruction that aims to provide students with the opportunities to develop the cognitive skills to become and remain informed, engaged, and scientifically literate. The instructional choices that teachers make belie their own values and epistemological beliefs and these, in turn, influence the development of students' beliefs which are taken beyond the classroom (Jones & Carter, 2007). For this reason, science educators need to be informed about the specific purposes of science education, the implications of various instructional strategies, as well as the values and views they are instilling in their students.

Importance of Elementary Science Education

Our North American society is becoming increasingly dependent on scientific and technological advancements despite a large portion of our population having very little understanding of these influences (van Aalderen-Smeets, Walma van der Molen, & Asma, 2012). Our expanding knowledge of science and technology influences almost every aspect of human life. Our understanding of the roles that humans and the environment play in shaping a future standard of living are being transformed. Survival and sustainability challenges faced by many nations and the efforts made to increase accountability for political awareness and involvement in these social responsibilities are impacting every country. There is a need to develop a diversely skilled generation within our globally competitive world despite limited resources and ranging priorities (McFarlane, 2012). In spite of these critical issues, negative and unengaging experiences in school are leaving many students uninterested in science. Allowing students to develop a negative or indifferent attitude toward science and technology will only lead to increasing challenges for our society. In this situation the general public will not only miss out on science-related employment opportunities, but they will remain uninterested, uninformed, and uninvolved in major decisions that should be made by a democratic population (van Aalderen-Smeets et al., 2012).

Arguments against the importance of science education suggest that most people are able to achieve a functional and productive standard of living despite their lack of scientific literacy. After all, the majority of North American adults can drive a car, bake, garden, or develop an exercise regime without much understanding of the intricate science that permits the success of these activities. When advocating for the reform of teaching practice in science education, we must consider whether scientific literacy is truly important and if it, as a primary goal of science education, is sufficient for our 21st century learners (McFarlane, 2013). What we do know is that ordinary citizens will be asked with increasing regularity to make decisions about issues underpinned by scientific and technological factors. Increasing health concerns, climate change, environmental sustainability, and technological advancements will influence everyone. Unfortunately, those without the foundation of scientific and technological knowledge will be disempowered and susceptible to being misled by those who have the knowledge and can exercise their democratic rights in the increasingly technological-dependent society (McFarlane, 2012).

On a global scale, Canada is considered to have a top-tiered education system, one we should be proud of; however, for an education system to elicit great success there is no time for rest in the pursuit of supporting students to meet their highest potential. As Canadian educators and educational researchers we cannot be complacent. The *Science and Technology* curriculum expectations provide ample room for teachers to touch upon relevant and current issues that impact our society and develop students' scientific literacy. Whether teachers are intentionally incorporating real-world connections into their science instruction or not depends greatly on their background experience with science, developed attitudes toward science, pedagogy, and their self-efficacy to teach science (van Aalderen-Smeets et al., 2012).

The Need for Change in Elementary Science Education

There was a significant curriculum shift in the 1960s following global events like the Cold War and the launch of the Russian satellite, Sputnik. These events acted as a catalyst for science education reform as many countries did not want to lag behind in these scientific and technological advancements. The curricular changes that resulted led to a focus on teaching students about the products of science, including current ideas, models, and theories. Additionally, students were to learn about how new information is developed through scientific exploration (Wong & Hodson, 2010). Although scientific and technological advancements continue to increase, in contrast, educational priorities, since the reform in the 1960s, have shifted away from science.

As previously mentioned, the 2011 TIMSS results demonstrate a declining trend in Ontario student science achievement since 2003. Fazio and Karrow (2013) attribute some of the unintended consequences, including this decline in science achievement, to the implementation of provincial standardized testing for select subjects, namely language and mathematics. Educational studies have demonstrated that students lose interest in science with age, or in correlation with the length of time they are enrolled in school (Let's Talk Science, 2013). Declining interest could provide a reason for achievement scores not only declining across testing cycles, but for Grade 8 students consistently achieving a lower relative score than Grade 4 students on the TIMSS as well, as indicated by Fazio and Karrow's position paper.

To teach science effectively, teachers need to present the practice of science in a critical and meaningful manner; therefore, they themselves need to have a fair understanding of the content knowledge and instructional strategies required. However, very few teachers enter an elementary teaching career with an academic science background (OCT, 2013b) or a feeling of preparedness to teach science (Jones & Carter, 2007). Many teachers, in fact, hold misconceptions about science, scientists, and science practices that end up being cyclically perpetuated through the teaching and learning process as a result of lacking intervention (Hodson, 2011). Foundational content knowledge is an advantage for teachers of all subjects; however an additional challenge is presented to those who teach science as they are expected to incorporate up-to-date science-related information within reform-based instructional practices (Marbach-Ad &

McGinnis, 2008). These expectations provide challenges for even the most well-prepared science teachers. Unfortunately, not all science teachers have content knowledge expertise or adequate training for reformed instructional strategies.

Scientific Literacy

A basic definition of scientific literacy is the ability to comprehend the processes and implications of science in the real world (Smith, Loughran, Berry, & Dimitrakopoulos, 2012). Scientific literacy is an internationally recognized educational slogan that has been used in science education and research for over 50 years (Hodson, 2011). Though scientific literacy is considered by most to be a desirable goal of science education, varied definitions leave much room for improvements in clarity and increased direction for curriculum development (Smith et al., 2012). In fact, the definition of scientific literacy and how to achieve it has been debated since the early 1900s (Hodson, 2003). Some educational experts believe that scientific literacy is the capacity to comprehend science-related newspaper articles to a reasonable degree while others believe scientific literacy is having the knowledge, applicable skills, and appropriate attitudes essential to a career in the STEM fields (Hodson, 2003).

For the purpose of this thesis, a person, or a teacher, who is scientifically literate has the ability to understand the nature of science, how new information is validated, and how a society's value system influences the cost-benefit analysis of implementing new advancements (Ontario Ministry of Education, 2007a; NGSS, 2013; STAO/APSO, 2006). It is important for teachers to have a developed scientific literacy in order for them to foster scientific literacy within their students. Aside from educational and career-based factors that support the need for scientific literacy, Let's Talk Science (2012) suggests that an increased level of scientific literacy is important for developing engaged and informed citizens who can make advantageous decisions that can ultimately improve one's quality of life.

International and National Assessments of Student Achievement in Science

There are several national and international assessments used as accountability measures for subjects like mathematics, language arts, and science. These assessments are typically cyclical with the purpose of ranking regions based on student achievement and to maintain consistent standards across countries. High-stakes assessments directly and indirectly communicate values and place pressures on teachers to modify/adjust their instructional decisions (Shaver, Cuevas, Lee, & Avalos, 2007).

Provincial Assessment

In Ontario, there is no internal provincial assessment for science, leaving teachers and administrators to rely on external reports to demonstrate current student achievement. The lack of curricular accountability leaves the value of this subject open for interpretation, but more often than not, science is left behind and treated as a subject of depreciated value compared to those that are formally assessed. International test regimens that test students' aptitudes in science, such as TIMSS and PISA, are highly valuable indicators of how effective our current system is and provide a notion for which areas need to be improved.

National Assessment

The *Pan-Canadian Assessment Program* (PCAP) is a national cyclical assessment, first administered in 2007. The PCAP is designed to measure student achievement for 13- and 16-year olds in science, mathematics, and reading. This assessment is conducted every 3 years. The purpose of this assessment is to collect data that will indicate the effectiveness of education systems in each province as well as support curriculum reform and the development of assessment tools (Council of Ministers of Education, Canada [CMEC], 2014). The most recent science assessment was conducted in spring 2013, and was designed to collect data on the science competencies of students within the areas of science inquiry, problem solving, and scientific reasoning. All 10 provinces participated in the 2013 PCAP with over 32,000 students completing the assessment. This 2013 assessment found that Ontario students performed above the Canadian average in science. More specifically, 94% of Ontarian students achieved at a baseline Level 2 proficiency or higher (EQAO, 2013). As part of the PCAP, contextual questionnaires are also administered among students, teachers, and administrators from selected schools as a component of the assessment. The results from these questionnaires aim to provide insight into the performance of students in each jurisdiction. Factors such as student cultural diversity, the unique school board organization of each jurisdiction, and the specific strategies used to enhance science teaching and scientific literacy in students (CMEC, 2014).

International Assessments

The *Trends in International Mathematics and Science Study* (TIMSS) is an international math and science assessment, first administered in 1995. Every 4 years, student science achievement is assessed using a current set of science content and scientific reasoning benchmarks. Results from this assessment are reported and translated to an international standing so that countries' achievements can be compared (EQAO, 2014). Of the 74 jurisdictions that participated in the 2011 TIMSS assessment, 15 achieved an average score significantly higher than Ontario’s, and another 13 achieved the same average. The TIMSS 2011 results also indicate that of the Grade 4 students surveyed, 48% reported liking science and 41% reported having a high level of self-confidence with regard to learning science. The corresponding numbers for Grade 8 students were 29% and 22%, respectively (EQAO, 2011). As previously mentioned, Fazio and Karrow’s (2013) paper reports that the TIMSS science scores for Ontario students have been declining for over a decade.

The *Programme for International Student Assessment* (PISA) is an international assessment which cycles through evaluating achievement in reading, mathematics, and science of 15-year-old students. Every 3 years this assessment is conducted with a major and minor domain. In 2012, 65 countries and regions, including 21,000 Canadian students from across the 10 provinces, took part in the PISA. The most recent assessment of science was in 2006, with the next science assessment expected for 2015 (Organisation for Economic Co-operation and Development, 2014). According to the 2012 PISA results, Ontario’s 15-year-old students’ achievement in science has stayed about the same since 2009. Additionally, Ontario matches the Canadian average in science achievement (EQAO, 2012a).

While these assessments may portray a strong and effective science education in Ontario, only TIMSS reports specifically on student achievement within the Grades 4 to 8 range. Additionally, none of these assessments are designed to evaluate students’ achievement in science based on the Ontario curriculum. While large-scale assessments do have a number of limitations (e.g., lack of support for students with learning disabilities, students with disadvantaged backgrounds, and students whose first language is not that of which the test is written), these assessments do create a sense of instructional accountability (Steele, 2014). In Ontario, elementary EQAO assessments in Grades 3 and 6 have resulted in a strong sense of accountability as this large-scale assessment has elicited specific curricular focus in terms of funding, PD, teacher support, and scheduling time specifically for language and mathematics.

Elementary Teachers' Attitudes Toward Science Education

It was not until the 1930s that a theoretical framework was developed to outline the constructs of human *attitudes* and how they influence behaviour. In 1935, G. W. Allport wrote the *Handbook of Social Psychology* through which he delineated definitions and theories of attitude. The work of L. L. Thurstone (as cited in Kiesler, Collins, & Miller, 1969) provided both a rationale and a methodology for measuring attitudes as a way to understand social dynamics. At this point in time philosophers, psychologists, practitioners, and researchers define attitude in various ways. Further compounding the confusion, many continue to interchange the term *attitude* with the term *belief*. For the purpose of this thesis, Fishbein's (as cited in Jones & Carter, 2007) delineation of attitudes and beliefs has been used to identify attitudes as a component of one's belief system, while acknowledging that both of these psychological constructs are interwoven and embedded in sociocultural contexts.

An attitude is a positive or negative predisposition toward something that is influenced by one's level of enjoyment, interests, values, and self-confidence creating a set of priorities that outline one's action agenda (Ernest, 1989; Pajares, 1992; Simpson et al., 1994). Bandura's (1986) social cognitive theory, as it relates to the social foundations of thought and actions, suggests that one's beliefs and corresponding attitudes are the most reliable indicators of the decisions a person will make. This being said, when a teacher walks into a classroom, his or her attitudes about science in society, science research, teaching science, and learning science influence his or her practice.

The attitudes of science teachers have more recently been differentiated into two categories. The first category represents the attitudes that teachers hold toward science, and the second category represents the attitudes that teachers hold toward teaching science. van Aalderen-Smeets et al. (2012) present a three-part model as a means of organizing the main dimensions influencing these attitudes. These dimensions include cognitive beliefs, affect, and perceived control. Each dimension includes corresponding subcomponents to provide a more thorough and specific outline for attitude development. A significant amount of research has demonstrated that teacher attitudes greatly affect pedagogy, student learning, and student attitudes (Fitzgerald et al., 2013; Fulmer, 2013; van Aalderen-Smeets et al., 2012). Teachers who indicate having lower science content knowledge in combination with poor attitudes toward teaching science have been found to negatively influence students' attitudes toward science and lower overall growth in student achievement (Jarvis & Pell, 2004). Though poorly understood, unraveling the complexities of teachers' attitudes toward science instruction plays a significant role in moving toward successful science education reform (Jones & Carter, 2007; Haney, Lumpe, Czerniak, & Egan, 2002).

As with teaching any subject, science teachers both consciously and unconsciously embed values through their teaching as they add, delete, and modify content to align the material with their current understandings and instructional strengths. Teachers need to be made aware of how their predispositions and value judgments toward science result in spoken and unspoken messages that influence students far beyond the classroom (Hodson, 2011).

Students’ Elementary and secondary science experiences have a great influence on the attitudes about pedagogical strategies and epistemological views of new teachers (Jones & Carter, 2007; Morrison, 2013). Martin-Dunlop and Fraser (2008) report that teacher candidates often describe feelings of apprehension about teaching science, which have been linked to their phobia of science itself. The traditional method of science instruction, typically demanding rote memorization, over reliance on textbooks, and countless worksheets turn many people away from the subject. Prospective elementary teachers who have had such unstimulating experiences often end up avoiding secondary and postsecondary science courses (Martin-Dunlop & Fraser, 2008). It is unfortunate that negative science education experiences may cause teachers to avoid teaching science or to justify designating science as a secondary priority. The evident cycle of ineffective or absent science instruction can easily go unnoticed for decades if it is not given precedence among educational authorities (Martin-Dunlop & Fraser, 2008).

Teachers’ own elementary and secondary science education experiences typically permit the development and solidification of attitudes toward science far before their teaching career begins (van Aalderen-Smeets et al., 2012). However, even teachers who begin their teaching careers with a positive predisposition toward science may struggle in the beginning. Pedretti’s (2003) study of 25 newly qualified teachers who identified themselves as having positive attitudes toward science found that they put very little focus and attention into their science teaching practices during the first 5 years of their careers. These novice teachers reported concerns about addressing moral-ethical issues, uncertainty about students' cognitive and emotional preparedness to address socioscientific issues, insufficient preparation time to develop appropriate learning activities, and low confidence in their ability to effectively assess student achievement within reform practices (Pedretti, 2003). The positive attributes that have been linked to teachers who hold positive attitudes toward science and implement reform-based practices in their science instruction include open-mindedness, a preference for indirect and inductive teaching, and independent thought and action (Jones & Carter, 2007). The attitudes that teachers have toward both science and teaching science have a profound impact on both the conscious and unconscious decisions made about all aspects of teaching, learning, and assessing (Jones & Carter, 2007).

Attitudes toward teaching also influence the level of motivation that a teacher has toward facilitating certain instructional practices, effectively determining the degree to which reform practices are implemented (Jones & Carter, 2007). PD opportunities that intend to improve elementary science instruction are often either too short for true reflection on practice and/or the focus is on the "how to" of one-time demonstrations or didactic hands-on activities for students. These efforts are well-intentioned, but often result in short-lived changes in one's teaching practice because negative attitudes are not specifically being shifted or improved, and, ultimately, the results are brief and unsubstantiated (van Aalderen-Smeets et al., 2012).

Pedagogical Content Knowledge

The concept of pedagogical content knowledge (PCK) encompasses how teachers go about using their content knowledge to facilitate student learning. A teacher's PCK also involves an understanding of students' common misconceptions regarding topical information and how students learn certain concepts most effectively (van Driel et al., 1998). The concept of PCK acknowledges that teaching is more than teachers delivering information and students absorbing it. Among educational researchers, it is understood that teachers' PCK is dynamic and evolves with increasing knowledge, experience, and reflection on practice (Nilsson & Loughran, 2012). PCK is highly individualized and is difficult to observe or measure due to the complex schema involved (van Driel & Berry, 2012).

Research has indicated that elementary science teachers tend to have limited science content knowledge that impacts their development of science PCK (Kind, 2009; Nilsson & Loughran, 2012). However, having extensive science content knowledge does not necessarily make for an effective science teacher. Science teachers also need to have the knowledge and skills to facilitate the learning of science for students with different learning needs (Kind, 2009). Due to the highly complex theoretical framework of PCK, there are still many controversies over what it entails and how to best foster it in teachers (van Driel & Berry, 2012). Kind (2009) suggests that if more research was done to identify the building blocks of successful science PCK then more effort could be implemented to foster these experiences and qualities in teachers through various learning experiences (i.e., preservice and PD).

Teacher Self-Efficacy

According to Kirik (2013), science content knowledge, classroom management strategies, participation in science activities both in and out of school, the number and quality of science teaching methods courses completed, science teaching experiences, attitudes toward teaching science, and context beliefs all influence an educator's science teaching self-efficacy. Self-efficacy, is another component of belief systems outlined by Fishbein (as cited in Jones & Carter, 2007). Self-efficacy is more commonly known as a component of Albert Bandura’s social cognitive theory of behaviour and motivation. Bandura’s theory of self-efficacy proposes that people are motivated to complete a task or action if they believe it will induce a favourable result. Bandura (1977) defined four sources of self-efficacy including mastery experiences, vicarious experiences, verbal persuasion, and emotional arousal.

When applied to the context of elementary science teaching, the theory of self-efficacy suggests that elementary teachers will be more willing to devote increased amounts of time, energy, and effort into teaching science, or to implement reform, if they believe that they have the ability to teach science effectively and that their science instruction will result in greater student achievement and learning (Kirik, 2013; Lumpe, Czerniak, Haney, & Beltyukova, 2012). Teachers who have taken more than the minimally required science context courses throughout their undergraduate degree report a stronger belief that their science instruction will result in improved student achievement (Hechter, 2011). Consequently, teachers with low self-efficacy for teaching science are less likely to experiment with new teaching strategies or tools in order to meet the needs of their students. Even teachers who are displeased with the results of their current practice will likely avoid making changes if they are uncertain that the changes will result in increased student achievement (Sowell, Southerland, & Granger, 2006). Intentionally increasing teacher self-efficacy through teacher education and appropriate PD has the potential to promote the implementation of reform and improvement within all aspects of education.

Influences of Teachers' Academic and Professional Background Experiences

There is an accepted understanding that teachers often teach in the way they themselves have been taught. Teachers' teaching performances have also been found to correlate with their personal beliefs about teaching and learning (Marbach-Ad & McGinnis, 2008). As students, many teachers experienced a type of science education saturated with textbooks and memorization. Calabrese Barton and Yang (2000) note that "textbooks and other curricular materials often hide the people, tools, and social contexts involved in the construction of science. The result is often a fact-oriented science that appears decontextualized, objective, rational, and mechanistic" (p. 875). A teacher's perception and attitude toward the subject of science and the influence science has on society is a crucial factor in propelling the implementation of science education reform (Kumar & Morris, 2005). Teachers' prior academic, professional, and personal experiences create filters used to categorize new information (Marbach-Ad & McGinnis, 2008), thus influencing the way they teach (Kumar & Morris, 2005; Morrison, 2013). If a teacher has not experienced a form of science education interconnected with current events, applicable activities, or scientific inquiry, new information about science instructional strategies will most likely be filtered through their pre-existing knowledge and pedagogy—effectively maintaining the status quo (Marbach-Ad & McGinnis, 2008).

Science Teacher Education

Following an undergraduate degree, in Ontario, aspiring teachers must complete a teacher education program at the Primary/Junior, Junior/Intermediate, or Intermediate/Senior level. Additionally, to teach at a publicly funded school in Ontario, every teacher must be certified by the Ontario College of Teachers (OCT, 2013a). OCT certification typically requires an undergraduate degree, a Bachelor of Education or transferred education degree, and a professional recommendation from their teacher education program.

Currently, all Ontario teacher education programs require J/I teacher candidates to take a general science methods course, irrespective of their undergraduate background (Ontario Ministry of Education, 2014). Inconsistencies in the outcomes of this course across programs are inevitable as the length of the course, the content taught, and the exit requirements are not mandated by the Ontario College of Teachers. These differences allow substantial room for interpretation with regard to the expectations of teacher candidates' confidence, skills, and knowledge required in order to teach science effectively.

Science Education Professional Development

Teachers' own teacher education experiences in combination with their working environment have been identified as factors closely tied to the potential success of educational reform (National Commission on Teaching America's Future, 1996). While acknowledging that academic science experiences greatly influence teachers' attitudes and self-efficacy toward their ability to teach science, many teachers arrive on the job without this advantage (Jarvis & Pell, 2004). The assumption that improving teacher preparation and professional development (PD) experiences will result in better teaching and enhanced student learning has caused much more attention to be focused on these tasks (van Aalderen-Smeets et al., 2012). Lotter, Rushton, and Singer (2013) propose that PD opportunities need to be long-term, provide considerable support, and focus on the improvement of beliefs and attitudes toward science and reform strategies to be effective. The current model of science education PD takes the form of 1- to 2-day seminars or workshops focused on teaching teachers how to implement demonstrations or prescribed hands-on activities. PD opportunities for science education should be aiming to meet the needs of the majority of teachers who require the intensive support to adjust their attitudes toward science and science teaching in order to implement and maintain reform teaching strategies (van Aalderen-Smeets et al., 2012).

Challenges With Teaching Science Education in Elementary Schools

There are many obstacles that interfere with teaching science effectively. Attitude development in young children that is carried into adulthood and then implanted among the next generation makes educational researchers question the most practical entry point for effective reform (Jarvis & Pell, 2004). A poor experience with science education as a student leaves many prospective teachers lacking a reasonable level of scientific literacy or even an interest in science. This negative impression creates a perpetuated stereotype of traditional science practices defined by textbooks and handouts (Jones & Carter, 2007). Though the subject of science holds significant potential for fostering critical and problem-solving skills, skills highly valued by education systems and society, science education is rarely an instructional focus, the topic of PD, nor the priority on the timetable.

Decline of Student Interest in Science

Young children are captivated by the opportunity to participate in science through discovery. The inquisitive nature of children indicates their persistent desire for a greater understanding of the world around them. They are naturally curious and do not hesitate to ask questions. They want to know why thunder makes a loud boom, how the leaves change colour in the fall, and what snow is made of. Unfortunately, our students' innate curiosity and interest in science begins to decline with age, or possibly with the amount of years spent in school (Bloom, 2006). In 2010, the Ipsos-Reid survey (as cited in Let's Talk Science, 2013) commissioned by the Canada Foundation for Innovation Monitor, which surveyed 2,600 students between the ages of 12 to18 years, found just that. Specifically, 78% of those between 12 and 13 years reported being somewhat to very interested in science, compared to 67% of individuals aged 14 to 16 years, and only 58% of those aged 17 and 18 years. These statistics beg the question: Do our students see relevance in their science education?

Time Allocated for Elementary Science Education

Whether learning occurs through inquiry or direct instruction, allocated time is considered to be "an exceedingly obvious variable" on instructional success (Carroll, 1989, p. 27). Time is not an independent factor; however, time allocated for each subject in the academic schedule implicitly communicates the value placed on each subject (Judson, 2013). While trying to ensure that students are adequately prepared for high-stakes testing, subjects left out of these tests often find their way to the bottom of the priority list (Griffith & Scharmann, 2008; Smith & Rottenberg, 1991).

While instructional time alone is not an independently reliable factor of student achievement, several studies have found a strong positive correlation between the two (Blank, 2013; Judson, 2013; Lavy, 2010). According to research that examined the 2006 PISA scores, instructional time in science is linked to a positive and statistically significant effect on achievement test scores for 15-year-olds in over 50 countries (Lavy, 2010). This positive correlation between time and achievement is mirrored at the elementary grades as well. In an American study, Blank (2013) found that the more time spent on science instruction the higher the science scores were on the National Association of Educational Progress assessment. In another American study, Judson (2013) found that teachers in states which factored science into accountability measurements consistently spent more time on science instruction than teachers in states where science does not factor into accountability assessments.

Results of research conducted by Clark and Linn (2003) found that instructional time is strongly correlated with student comprehension of complex concepts in science. Though many teachers recognize the valuable skills that science instruction promotes, they admit to neglecting science instruction and decreasing scientific inquiry efforts as high-stakes testing dates approach (Smith & Rottenberg, 1991). High test scores are not the means to an end, but an indication of elementary science education fulfilling an effective role as a preparatory step toward our students having the necessary knowledge and problem-solving capabilities required for our increasingly complex world (Blank, 2013).

In Ontario, school boards are independently responsible for determining instructional time allocation for schools. The Ontario Ministry of Education (2009) does suggest a typical 100–120 minute learning block for daily language instruction and a 60–75 minute learning block for daily math instruction; however, there is no instructional time recommendation for science. The only document found to recommend allocations of time per subject for the province at large was the Arts Education Consultants of Ontario (2012). This document suggests that schools in Ontario allocate 180–225 minutes for science teaching out of the typical 1,500 minutes instructional week, which translates to only 12–15% of total instruction time. This, however, is just a recommendation. Even with the suggestion of 180–225 minutes of science instruction per week, teachers make independent decisions based on personal preferences and perceived needs of their students. Acknowledging the fact that no internal accountability assessments involve science in Ontario, it can be assumed that the effects of instructional values and priorities, similar to those previously stated about cases in the United States, translate equivalently to Ontario classrooms and student populations.

Resources Available for Science Education

The allotment for science resources can be limited based on a school's overall budget, administrative choices, and/or degree of teacher advocacy for additional resources. Textbooks are a standard resource used in the science classroom and are sometimes used to supplement teachers' varying levels of content knowledge. Unfortunately, textbooks can be very expensive, therefore limiting the frequency that updated texts can be purchased. There is no dispute that topics covered within the *Science and Technology* curriculum unit strands: *Understanding Life Systems, Understanding Matter and Energy, Understanding Structures and Mechanisms*, and *Understanding Earth and Space Systems* have evolved rapidly over the last 5 years. Outdated textbooks can leave students with obsolete and incomplete perspectives of scientific understandings, how these understandings have evolved over time, where we stand now and what we predict for the future.

Some of the most common materials used for science instruction include the physical facilities (e.g., laboratory space, sinks, and electrical outlets) and laboratory equipment or supplies (e.g., microscopes, chemicals, and building materials). The list of material resources that can be used to support science instruction tends to be quite lengthy when compared to the material lists for other subjects, but that is no reason for inadequate supply. American studies have also identified the inadequate supply of resources for science instruction (Appleton, 2002; Appleton & Kindt, 2002; Smith et al., 2013), which has been found to influence teachers' willingness and desire to teach science (Appleton, 2002). Typically, schools in lower socioeconomic areas tend to have fewer resources due to unequal school fundraising opportunities (Smith et al., 2013). Additional resources used for inquiry investigations also tend to be limited and outdated due to budget decisions within schools. Resources that are available to some teachers are not used due to a limited understanding of how to use them. A limited number of J/I teachers certified with science as a teachable subject, restricted time allotment, and tight budgets tend to result in science instruction not meeting its fullest potential.

Reform-Based Elementary Science Education

Historically, the development of reform initiatives within science education have been in response to world events that have drawn immediate attention to the need for increased performance. A sense of urgency regarding student learning alongside new policies directed at improving achievement outcomes appear to be highly motivational for reform implementation (Rudolph, 2002). Recognizing that this is a reactionary trend rather than a preparatory initiative should cause worry for the many stakeholders who invested in the results of education. At this point scientific and technological advancements along with environmental decline are happening at such a profound rate that it is obvious that efforts to improve science education will only benefit everyone.

According to Hodson (2011), reformed science curriculum standards should incorporate the purpose of developing activists; that is, citizens who are willing to recognize the challenges facing our world and work to realign our society's values for the best interests of the biosphere, the ultimate nonrenewable resource. Science education can offer students the opportunity to question and reflect upon their own beliefs, attitudes, and values as they relate to personal and lifestyle choices (Hodson, 2013). This idealistic perspective on reform meets the needs of our present and future generations, but this shift in perspectives and values will not happen overnight.

The National Science Teachers Association (NSTA) is currently the world's largest organization focused on advocating and supporting excellence and innovation in science teaching and learning. The NSTA (2014) promotes scientific inquiry as a necessary aspect of daily curriculum for all students at every grade level. Throughout the last decade, several reform documents have been published that highlight the value and importance of early inquiry experiences, specifically to establish problem-solving skills that empower students to actively engage in our increasingly scientific and technological world (NSTA, 2014).

From a North American perspective, countries such as the Unites States are actively seeking advancement in their science education efforts, are frequently publishing reform documents, and are implementing initiatives for the advancement of their science curriculum. The American Association for the Advancement of Science (AAAS) developed and implemented *Project 2061* in 1985. This long-term initiative sets curricular benchmarks aimed to re-establish the purpose of science education by encouraging students to make sense of how the world works, to think critically and independently, and to lead interesting, productive, and responsible lives in our society (AAAS, 2013). In July of 2011 the National Research Council released *A Framework for K-12 Science Education* to support the development of successful science, technology, engineering, and mathematics education. More recently, in 2013, the Next Generation Science Standards (NGSS) educational framework was published outlining the 21st century learning goals in science that support the development of informed citizens who are prepared with the necessary skills and knowledge for higher education. In the United States each state has the autonomy to choose which standards their schools will adopt, whereas in Canada, each province has a mandated curriculum regulated by the province.

In Canada, the *Common Framework of Science Learning Outcomes*, published in 1997, is the most recently published national science education reform document (CMEC, 1997). Though Canada's provinces are independently responsible for determining curriculum expectations, this national document was published with the purpose of maintaining consistency across the country. The Ontario *Grades 1–8 Science and Technology* curriculum document was published in 2007. Despite current literature uniformly stating that our students require current and applicable knowledge with an emphasis on the development of 21st century skills, little curriculum reform within science is on the rise in Canada. At the present time, the Council of Ministers of Education, Canada and Ontario's Ministry of Education have no plans to revise these science education documents (Ontario Ministry of Education, personal communication, January 31, 2014).

Pedagogical Reforms in Science Education: Scientific Inquiry

Inquiry is considered to be a reform practice in education, though its roots are found among the educational research of renowned educators such as Piaget, Pestalozzi, Dewey, and Montessori, who similarly advocated for active student engagement to foster authentic learning experiences (Ireland, Watters, Brownlee, & Lupton, 2012). An inquiry-based learning approach starkly contrasts the allegedly more surface-level observation, description, and laboratory experiments with preset outcomes that long have been the standard of even the best science education.

Inquiry is a constructivist teaching method. “Inquiry-based laboratory investigations at every level should be at the core of the science program and should be woven into every lesson and concept strand” (NSTA, 2007, p. 2). Inquiry, as defined by the NRC (2000), includes students asking their own questions, devising experimental designs, justifying explanations and connecting those explanations to scientific knowledge. Inquiry learning is considered by many to be a contemporary constructivist pedagogical strategy because it allows students to learn in an individualized manner by drawing on personal experiences and curiosity (Ireland et al., 2012). To facilitate science through inquiry, teachers must use approaches that base learning experiences around solving authentic problems. This process allows students to model methods of scientists in both procedures and data analysis (Crawford, 2000).

Banchi and Bell (2008) acknowledge that many elementary teachers struggle with the interpretation and facilitation of scientific inquiry. They developed a four-level continuum that describes scientific inquiry from very structured low-leveled inquiry to high-level inquiry where students develop and direct their own inquiry processes. Level one is called confirmation inquiry: at this stage the teacher provides students with a question and the procedure, or method, through which to confirm a theory (i.e., the expected results are already known). The second level is known as structured inquiry: teachers still provide the question and method; however, students are expected to develop an explanation for the results on their own. The third level is called guided inquiry: the teacher provides the question and the students develop their own procedure and explanation for results. Lastly, the fourth and highest level is known as open inquiry. At this level, students perform as a scientist would by developing questions, designing and following through with a method to pursue answers, and communicating the results. The purpose for this continuum is to support teachers' understanding of the scaffolded processes required for scientific inquiry skill development. Students need substantial experience with these lower-leveled processes prior to being able to successfully work through to the highest level. Although scientific inquiry is considered the model for best-practice in science education, it is more accurately a primary component of best-practice as student learning requires a variety of support types and experiences.

Chapter Summary

The challenge for all who are invested in improving education is to generate an educational system that utilizes the innate curiosity of children so that a motivation for learning is stimulated not solely for the purposes of formal education but to promote lifelong learning (Yager, 2009). There is no better time to improve science education than today. Major policy debates that will have dramatic societal impacts about such topics as cloning, renewable energy, and global climate change require a scientifically informed citizenry in order for all voices to be heard and for informed decisions to be made.

National and international assessments that speak to student achievement in science can provide insight into the state of overall student achievement, but are not specifically tailored to the Ontario context. Within the classroom, the attitudes of science teachers toward science need to be examined and considered for the distinct influence that they have on student achievement and longitudinal success. The influences of teachers' background experiences, limited resource availability, limited time allocation for instruction, and the ability to implement various teaching strategies impact the success of every subject, but very distinctly impact the success of science instruction. The fact that education produces educators results in an uncertain point of ideal intervention for science education reform. What is for certain is that teachers need to be increasingly adaptive to new teaching and learning strategies in order to meet the evolving needs of their students. In order for this to happen, teachers need to receive appropriate and effective support from their administration, school boards, and the Ministry of Education.

The next chapter outlines the mixed-methods design that will direct this study. The research context is described as it pertains specifically to the elementary Ontario education system. Participant selection is explained. Data collection and data analysis processes are described for both qualitative and quantitative procedures. Methodological assumptions and ethical considerations are explored.

CHAPTER THREE: METHODOLOGY

The aim of this study was to explore the current state of Grades 4 to 8 science education in Ontario. Specifically, this study was designed to explore the attitudes and experiences that J/I teachers bring to their science teaching practices. Teaching strategies being implemented, available resources, and time allotment for science instruction were also examined.

This chapter describes the methodological approach to the study. A two-phased mixed methods research study was conducted that integrated both quantitative and qualitative data. The instruments for data collection consisted of an online survey (that collected quantitative and qualitative data) and follow-up interviews (that collected qualitative data). A mixed methods research design was selected as most appropriate to answer the research questions, which involved collecting quantitative descriptive and narrative data. Casting a wide net for data collection was done intentionally to elicit a large sample size allowing maximum variation across participants. Data collection in this explanatory study aimed to describe the status of various phenomena currently impacting the effectiveness of elementary science education in Ontario.

Research Context: Elementary Science Education in Ontario

The range of Grades 4 to 8 is considered to be a critical time to foster students' intrinsic interest in science and to build their self-confidence (Bressler & Bodzin, 2013; Fitzgerald et al., 2013). Positive and enriching experiences with science from an early age enable students to see themselves as pursuing science-related careers and/or involved with science (Bressler & Bodzin, 2013). For students to meet this potential they need teachers who can effectively facilitate and scaffold the learning of science content and skills. Investigative research has identified teachers' academic background and personal experiences with science as playing a major role in preparing them to deliver quality science instruction (Appleton & Kindt, 2002; Bulunuz & Jarrett, 2010). Additionally, factors such as resources, funding, time allotment, and most importantly, teachers' attitudes and self-efficacy influence the effectiveness of science education, and ultimately, student success (Clark & Linn, 2003; Morrison, 2013; Thomson & Gregory, 2013).

Research Questions

The research design used both an online survey that collected both quantitative and qualitative data as well as follow-up interviews. This methodology is well-suited to address the research questions outlined below because it allowed the complementary strengths of both qualitative and quantitative data collection to account for large-scale survey and small-scale interview input (Patton, 1990). Both quantitative and qualitative data sets were used to uncover the specific factors that are currently influencing the state of Grades 4 to 8 science education in Ontario from the perspective of J/I teachers. The five research questions that guided this study were:

- What attitudes do J/I teachers have toward teaching science?
- What science-related academic and professional experiences do J/I science teachers have?
- What teaching strategies are J/I science teachers currently using to teach science?
- What support resources are available to teach science in elementary schools?
- How much instructional time is allocated for science in elementary schools?

These research questions elicited data that were analyzed and used to provide insight into the level of preparedness and the amount and variety of resources that J/I science teachers have to teach science. Additionally, these questions were designed to prompt teachers to reflect on the supports and limitations involved in their current science teaching practice.

Research Design

The use of a mixed-methods research design involves reporting on a research problem through the collection and analysis of both quantitative and qualitative data (Creswell, 2012). A "concurrent triangulation method design" as described by Creswell, Plano Clark, Gutmann, and Hanson (2003) was used for process of data collection, analysis, and presentation of results. This method involved a triangulation of quantitative and qualitative data collection, separate data analysis, and an integration of the two throughout the interpretation and discussion stages of this report. In the case of this study, using a mixed-methods design allowed for the weaving of various strengths and weaknesses of quantitative data collection (i.e., large *N*, trends, generalized themes) with those of qualitative data collection (i.e., small *n*, details, comprehensive) (Patton, 1990).

This study followed a two-phased explanatory design model described by Creswell and Plano Clark (2007). The notation of this study can be written as QUAN (qual) → qual. These methods were used in sequence beginning with an online survey ($N = 219$) that collected predominantly quantitative data with some qualitative data (open-ended questions), followed by semi-structured individual interviews with participants ($n = 6$) purposively sampled from survey participant pool. Using this model to guide the research design enabled the researcher to gather initial insight into the current state of elementary science education in Ontario and then complement that information with detailed personal accounts from the experiences of individual teachers that allowed for greater depth of investigation than if only one type of data had been collected.

Instrument Development

This section provides a brief rationale for the development of both the survey and interview tools used to collect data for this study.

Survey. The development of the survey involved a review of several surveys used in large-scale research to collect data about science teachers and science instruction in the United States. Several questions used in the survey for this study were modified from the 2004 and 2007 editions of Horizon's Pan-Canadian Assessment Program (PCAP) Teacher Questionnaire (CMEC, 2004, 2007) as well as the 2012 National Survey of Science and Mathematics Education Science Teacher Questionnaire (Horizon Research, 2012). Other questions were developed by the researcher to elicit information specific to the research questions or to the educational context in Ontario. The survey questions were imputed into the SurveyMonkey software. The survey was comprised of 39 questions broken down into four sections requiring approximately 20-30 minutes to complete. A final question asked if participants would be willing to participate in a follow-up interview.

Prior to data collection, a critique of the survey questions was conducted. The purpose of this portion of the survey critique was to determine estimated completion time, confirm clarity of question wording for participants, ensure the question order was logical, and ascertain whether all of the questions applied reasonably to the intended participant population of Ontario teachers. One principal, two full-time teachers, and two occasional teachers known to the researcher reviewed and provided feedback for this tool. The researcher's supervisor and committee also reviewed and provided feedback on this tool. This process resulted in a few redundant questions being removed, altering the wording of a few questions for clarity, and changing the Likert scale options on a couple questions.

The second portion of the critique was conducted with the purpose of ensuring that the online survey interface worked properly based on question order and participant response (question logic). This portion of the critique involved three full-time teachers and two occasional teachers completing a mock version of the survey online. This process resulted in several minor text edits, and a couple changes to the response question logic.

Interview. The interview protocol included 19 questions and was designed as an extension of the survey. The content questions outlined in the interview protocol follow the same themes as the survey (e.g., teacher attitudes and experiences, teaching strategies, resources, and time, etc.) with the intention of collecting data of greater detail from participants regarding their personal stories and experiences. The interview was semistructured and was conducted over the phone for easier participant access.

The interview protocol refinement process was conducted to test the interview questions for clarity, order logic, and the degree to which they would elicit the intended type of answer. The interview questions were sent to five people including one principal, two full-time teachers, and two occasional teachers with request for feedback and then reviewed by the researcher's supervisor and committee. The result was that a couple questions were removed, and two questions were re-written for clarity. Lastly, a pilot interview was conducted with a colleague of the researcher with a similar academic background. This interview was conducted to ensure clear recording technique, expected interview length, appropriateness of question order, and clarity of questions, and to increase the overall validity of the research tool. The result of this portion of the pilot was a couple questions being broken into several smaller questions and one question was made more specific.

Data Collection

As the investigation involved human participants, ethical clearance from the degree-granting university was required prior to beginning this research. The researcher decided to independently distribute the survey rather than involve specific school boards as gatekeepers so that participants from a wider geographical range in Ontario could participate. Both STAO and Youth University are educational organizations in Ontario that supported the distribution of the survey by posting the link on their websites and/or sending the link and information to their listserv of Ontario teachers. An outline of the methodology, potential risks and benefits of participating in the study for participants, measures taken to reduce any risks and maintain anonymity of participants, and a list of educational organizations that would act as gatekeepers was submitted to the Research Ethics Board (REB). Additionally, both the survey and interview question sets, as well as anticipated correspondence between the researcher and future participants were submitted for review. The ethical clearance for this study was modified once in order to include a second educational organization who sent the survey link out to their listserv. Research Ethics clearance (file # 14 – 046 - FAZIO) was obtained in September 2014. Information about the study and the link to the online survey were sent to the approved educational organizations for data collection to commence at the beginning of October 2014.

Survey Data

The survey was designed to elucidate both the demographic data as well as data that will describe the attitudes and teaching strategies used by J/I science teachers.

Nominal and ordinal data were collected in addition to textual data from the open-ended response questions. Survey questions can be seen in Appendix A. Several opportunities for additional comments were provided throughout the survey. These qualitative data provided the researcher with additional detail to support and expand on quantitative findings. The survey questions were designed to gather information that helped the researcher to explore the experiences, attitudes, perceptions, and feelings of preparedness that J/I teachers in Ontario have toward teaching science.

The final question of the survey asked participants whether they would be interested in being contacted to participate in a follow-up interview. Initial analysis of both the quantitative and qualitative data collected from the online survey served as a support for the progressive development of the semistructured interview protocol. Quantitative data analysis procedures are discussed in a following section.

Interview Data

Participants selected for a follow-up interview were contacted via email to establish an agreeable date and time for an interview. To allow for a larger geographical range of interview participants, and to eliminate travel time and location bookings, interviews were conducted over the phone. The interview required approximately 30 minutes to 1 hour for completion. The interview process followed a semistructured format, which began by requesting the same type of demographic information as in the survey. An interview protocol involving the 19 open-ended interview questions (as seen in Appendix B) was used to ensure a moderately consistent format with question asking and anecdotal note taking. These questions were developed to elicit responses that expand on and provide additional detail through personal accounts to the data collected from the survey. Using open-ended questions allowed for participants to freely express their perceptions, lived experiences in schools, and their attitudes toward teaching science. These responses provided contextual evidence that either aligned or contradicted with the data obtained from the survey. Each interview was audio recorded and transcribed by the researcher. Anecdotal notes were made throughout each interview with the purpose of keeping note of specific details or additional points that provided notable information. Audio recording files and transcription files were stored electronically and backed up. Transcriptions were member checked by each respective interviewee.

Participants

Participants in this study can be described as J/I teachers who currently teach science to students in Grades 4 to 8 in Ontario. This is a demographically diverse population as teachers from school boards across Ontario represent rural, urban, and suburban areas, in low, medium, and high socioeconomic areas. It is due to this diversity that casting a wide net across all of Ontario was necessary by sending out survey links and posting the link in virtual locations made the survey accessible to a wide range of Ontario teachers. Access to participants for this study was facilitated through organizations like the Science Teachers' Association of Ontario (STAO) and Youth University at Brock University, online Ontario teacher forums, and snowballing.

The chance to win one of four $25 Chapters gift cards was used as an incentive for complete survey participation in the online survey. Participants who wished to participate in the draw were asked to leave their emails at the end of the survey. The emails of the participants (*n* = 162) wanting to be entered into the draw were assigned a number (1 to 162). A random data-generating tool was then used to select the four participants who would win a gift card. It was stated in the consent form that completion of the survey was the only requirement to have a chance to win the gift card that that indication of willingness to participate in a follow-up interview would not impact the results. Additionally, it was noted that participant emails for this question would be confidentially destroyed by June 2015.

Survey participants. Participation in this study was voluntary. Advertisement for participation indicated preference for elementary teachers who teach science at the Grades 4 to 8 level. A total of 249 people responded to the survey. Participants who indicated that they taught either below or above the Grade 4 to 8 range or who did not complete more than 20% of the survey were removed from the data set prior to data analysis. Two-hundred and nineteen survey participant data sets were used for analysis. Upon clicking on the survey link potential participants would have to agree to the terms included on the consent form prior to having access to the survey questions.

Interview participant selection. Participants who completed the survey had the option to indicate willingness to be contacted for a follow-up interview. Of the 219 participants who completed the survey and met the required conditions outlined above, 55 (30.73%) said that they would be willing to participate in a follow-up interview; however, only 46 left their emails and only 36 had also completed the survey to a satisfactory degree. Participants were purposively selected with maximum variation sampling in order to collect data from participants representing the widest range of chosen characteristics (Creswell, 2013). The participant selection process was dependent on a spectrum developed by the researcher to represent a range of lowest to highest scores relating to the participants' use of various instructional resources (Appendix A –

Q. 24) and reported frequency of various science instructional strategies (Q. 28). Both of these questions involved a frequency scale with responses that were scored from 1 to 5, with 1 being *never* and 5 being *always* or *very frequently*. Both of these questions were comprised of multiple components. The score for each component of each question was used for the score calculation. The aggregate score for each potential interview participant was determined based on these scales. Higher frequency of resource use and higher frequency of instructional strategy use resulted in a high score. Potential interview participants were then ordered from lowest to highest total score creating a spectrum that was then divided into three groups of 15 or 16 people to correspond with low, medium, and high scores. This categorization was done to indicate teachers who had a low, medium, or high relative self-efficacy to teach science to students with various needs and relative level of pedagogical variation.

Participants' rating of feelings of capability to teach science (Q. 21: I consider myself: *a specialist, very capable, capable but prefer other subjects, or not comfortable*) and their years of teaching experience (Q. 6) were then used to select two interviewees with a range of attitude toward teaching science and years of experience from each low, medium, and high category. This selection process was used so that the researcher would be able to gather data from participants with the widest ranges of attitudes, experiences, and practices. Those who were selected for an interview were contacted via email with the interview consent form attached in order to establish an agreeable date and meeting time. While the survey was used to identify big picture themes and factors that are currently influencing the state of elementary science education, the follow-up interviews were used to refine, explain, and support the identified themes and factors in greater detail.

Data Analysis

For this study, data collection, analysis, and recording were conducted in an integrated pattern. Quantitative data gathered from the survey were statistically analyzed using the statistical functions on the SurveyMonkey program and MS Excel. Qualitative data collected from the open-ended question in the survey and follow-up interviews were analyzed by hand through an inductive and deductive coding process. Both types of data were compiled and analyzed indicating themes and patterns that were used to develop responses to the overarching research questions.

Validity of the data collected and the themes elicited from the findings in this study were ensured to the greatest degree possible. Strategies to support validity include triangulation and member checking. This process was conducted to confirm that the verbatim transcripts accurately expressed the views of each participant and to allow for any necessary clarification. These validation processes ensured that the findings are grounded in the data, that coding themes selected were appropriate, and that inferences that were made align logically with the data (Creswell, 2002).

Quantitative

Nominal and ordinal data were collected during this study. The majority of the quantitative data are presented through descriptive statistics. These data include demographic information that assists the researcher in knowing the breakdown of participant representation based on several characteristics (e.g., age, gender, years of teaching experience). Descriptive statistics also provide a breakdown of the proportions of survey participants' attitudes, teaching strategies, use of resources, time spent on science instruction, and the availability of various support systems.

Nonparametric statistics do not assume normal distribution and work well for a sample size above approximately 30 (Salkind, 2008). A chi-square test for independence was performed on several sets of nominal data from the survey. These sets included the explanatory variables B.A. and B.Sc. The response variables included capability levels, degree of science as a personal priority, professional experiences, and teaching strategies. A chi-square goodness-of-fit test was used on the frequency distribution of time spent on science instruction by survey participants. The results of these analyses will provide broad data trends that assisted the researcher with answering the research questions.

Qualitative

Qualitative data were collected from both the survey and the follow-up interviews. As suggested by Creswell (2012), the researcher began this aspect of data analysis by reading through the survey data and transcriptions several times. This process allowed the researcher to develop a deeper and more comprehensive understanding of patterns within the information provided by participants. Analysis of qualitative data involved both inductive and deductive coding. Qualitative data collected in the follow-up interviews served the purpose of eliciting additional details and clarification of the qualitative data collected from the survey.

Survey. Qualitative survey data were downloaded from the survey program for analysis. The qualitative data was initially inductively coded to elicit overarching themes. A portion of the qualitative data from the survey were then deductively coded for further organization against an accepted model of leveled scientific inquiry teaching methods. Coding procedures used for these data are described below.

Interviews. Audio recordings of interviews were transcribed into textual data. Accuracy of transcriptions was member checked by interviewees. Anecdotal notes from each interview were kept within appropriate files and used to flag certain data during the qualitative data analysis process of coding. Again, an initial analysis of the transcribed data was conducted as the researcher read through the data to get an overall sense of the information prior to breaking it apart. At this time comparisons between teachers, schools, and school boards were made through the analysis of data from each interview. The textual data from each interview were then broken up and combined with the other responses for each interview question. Data were then coded inductively by interview question.

Coding. Coding was done using MS Word and hand coding analysis. This process was used in order to maintain organization and consistency among codes (Creswell, 2012). Electronic files of textual data were stored in a password-protected program. Printed textual data were analyzed by coding. These hard copy documents were stored in a secured location. Descriptive coding was used to help analyze qualitative text for information that addresses the overarching research questions. A process of open coding was used to identify descriptive codes that allowed the researcher to describe each datum segment rather than using an analytic approach to infer meaning; this maintained the explanatory nature of this study. The first stage of open coding was done to identify data portions and begin the process of identifying patterns by labeling each portion with a descriptive code. The second stage of coding was done to reconfigure descriptive codes to ensure greater consistency among the large amount of text (Saldana, 2009). Initial codes were streamlined to form groupings of similar codes and clustered together before devising overall themes. Creswell (2013) refers to the process of developing and aggregating categories among codes as the procedure utilized to segment and label textual information to isolate descriptions and cluster together similar ideas into themes. Major and minor themes were identified based on codes to develop greater understanding of central factors influencing elementary science education.

Methodological Assumptions

Precise demographics of the participating teachers were unknown until data were analyzed. However, considering that participation in this research was optional, it was expected that those who were willing to participate are those who are already invested in raising awareness about the state of science education and would like to see it improve. Likewise, teachers who have little vested interest in the effectiveness of science education may be less likely to participate.

Because it is difficult to assess the degree of accuracy in self-report surveys, it was assumed that each participant answered the questions in the survey with a reasonable degree of veracity. The online survey offered both quantitative and qualitative questions pertaining to participants' teaching practice, attitude toward teaching science, and perception of preparedness to teach science. While the researcher assumed a high degree of accuracy in the participants' responses, it can be assumed that there was some degree of a rhetoric-practice gap as teaching intentions and teaching actions do not always align.

Ethical Considerations

This research involved human participants sharing their thoughts and lived experiences. For this reason, numerous ethical considerations needed to be made throughout the duration of the study. These ethical considerations required the clearance from the Social Science Research Ethics Board (REB) of Brock University prior to the commencement of research.

Survey participants were made fully aware of their rights and responsibilities as a research participant in this study upon reading and indicating that they have read the consent form attached to the online survey. There was no obligation to complete the survey, and survey participants were made aware of their right to exit the survey at any time. Interviewees indicated at the beginning of their audio-recorded interview that they had read and agreed to all of the terms and conditions included on the interview consent form. Participants were also made aware of their right to request that their submitted data would be removed from the collected data pool at any time. Participants will also be made aware of the possible outlets for dissemination.

The researcher maintained participant confidentiality throughout all aspects of this research and will continue to do so during dissemination. The names of interviewees were not recorded in any aspect of the interview results. Instead, interviewees were assigned a number based on the order that they were interviewed. Data were electronically stored and backed up within password-protected files on the researcher’s personal computer. Throughout this study, every reasonable effort was made to ensure that questioning methods and data collection, analyses, and presentation met the ethical standards outlined and approved by the REB.

Limitations

This study employed a survey that collected both qualitative and quantitative data from J/I teachers who teach science to students in Grades 4 to 8 and follow-up interviews with purposively selected survey participants. The researcher decided to distribute the survey independently rather than through individual or select school boards which would have required multiple REB clearances. Rather, the survey link and related information was posted on educational forums for teachers at the J/I level and sent out to the list serves of two educational groups, STAO and Youth University. This proves to be a limitation as only teachers who are members of these groups had access to the survey. Additionally, school boards that serve jurisdictions across Ontario with higher populations (i.e., the GTA, Ottawa) were better represented by participant survey completion than school boards that serve less populated jurisdictions. Although the survey may have not reached as many elementary teachers as it would have if it had been sent out through school boards, twice the expected number of survey participants responded to the survey and a wide range of school boards in Ontario (68.05%) were represented. According to the Ontario Ministry of Education (2013c), there were N = 82, 645 (female = 81% and male = 19%) full-time elementary educators in 2012. Approximately half of this population would teach at the J/I level (Grades 4–8). If only 219 teachers from the approximate n = 41, 322 J/I teacher population were surveyed, this indicates a response rate of about 0.5%. In order for more detailed inferential statistics to be performed a larger sample size would be required.

The ethical clearance for this study detailed that all survey questions would be optional. This resulted in unequal total responses for each question which complicated the presentation of some of the statistical data. Furthermore, self-selection bias is also considered to be a limitation with this study as it is likely that teachers who have a moderate to high level of confidence with teaching science would volunteer themselves to participate in a survey about science education. When asked about their level of comfort with teaching science, 63.60% of survey respondents reported that they felt capable to teach science and that they enjoyed it. Additionally, participants who indicated willingness to participate in a follow-up interview would be expected to follow the trend of demonstrating moderate to high levels of confidence with teaching science. Of the 36 participants who volunteered for an interview, 20 reported that they felt *very capable* and seven reported themselves as *specialists*. A non-representative bias was caused by a much higher than expected number of participants with a B.Sc. participating in the survey. About 30% of the survey participants reported holding a B.Sc., though, according to the statistics provided by OCT (2013b), only 8.7% of J/I teachers hold this degree. This greater representation of participants with B.Sc. degrees does have positive implications for the inferential statistics that could be done to compare the attitudes and instructional qualities to those with B.A. degrees.

Although the interview data were collected for the purpose of triangulating the survey data, a higher number of interviewees would have provided more breadth of responses. A few more interviewees may have provided additional data to support the claims that have been made by providing added breadth to the data. Additionally, half (n = 3) of the interviewees held B.A. degrees while the other half held B.Sc. degrees. If more participants with a B.A. had been interviewed a better understanding of the typical experiences had by J/I teachers while teaching science could have been developed.

Chapter Summary

This chapter provided an overview of the mixed methods research methodology used in this study. The research questions outlined in chapter 1 were addressed through a research design soliciting quantitative and qualitative data through a survey and qualitative data through follow-up interviews. Ethical clearance was granted prior to the initiation of research. Research tools were reviewed by educational researchers and teachers prior to data collection to check for validity and reliability. Following data collection, descriptive statistics and chi-square tests were formed on quantitative data. Qualitative data were analyzed using inductive and deductive coding. Achieving triangulation through a survey and follow-up interviews allowed for a broad understanding of the factors that influence the quality of elementary science education in Ontario. The limitations of this study included the clustered locations of survey participants (e.g., teaching in urban and suburban areas) and the ethical consideration that permitted participants to skip survey questions. Through the corroboration of data, the resulting themes, patterns, and statistical tests used to analyze data are detailed in chapter 4.

CHAPTER FOUR: RESULTS

This chapter describes the results from the analyses performed on the data gathered throughout this study. This study was designed to explore the current state of Grades 4 to 8 science education in Ontario. The research design for this study was a sequential two-phased mixed methods explanatory design denoted as QUAN (qual) → qual. Data were collected from two sources: an online survey and follow-up interviews. The survey data were collected between October 2014 and January 2015 from 219 J/I teachers who teach science in Ontario. Six interview participants were purposefully sampled from the survey participant population. Interviews were conducted between January and February 2015.

This study addressed five research questions:

- What attitudes do J/I teachers have toward teaching science?
- What science-related academic and professional experiences do J/I science teachers have?
- What teaching strategies are J/I science teachers currently using to teach science?
- What support resources are available to teach science in elementary schools?
- How much instructional time is allocated for science in elementary schools?

In this chapter, the participants from the survey and interviews will be described as "survey participant(s)" or "interviewee(s)," respectively. The presentation of data begins with an outline of survey participant and interviewee demographics. Following this, teachers' academic professional experiences along with their self-reported attitudes about teaching science are discussed. The instructional strategies used to teach science as well as the material resources and human supports (e.g., colleagues and administration) available to these teachers are presented and discussed. Next, the time allotments for science instruction based on typical instructional weeks are presented. Also, the results from inferential statistics that analyzed the influence of teaching experience and academic background on teacher attitudes, time spent in science PD, and the frequency of skill-developing instruction are outlined, followed by a chapter summary.

The results from this study are organized by theme with quantitative and qualitative results from the survey and interview reported in an integrated manner when appropriate. The survey consisted of 39 questions (see Appendix A) that participants could opt out of as per ethical requirements. Due to some variability in response rates across survey questions, the descriptive statistics and inferential statistics are presented along with an exact participant response number. The responses from the open-ended survey questions are presented in a summary with emergent themes. The interview consisted of 19 questions and eight subquestions (see Appendix B). The interview data were arranged so that the responses collected for each interview question were analyzed and coded together.

Demographics

This section presents the demographics and current teaching assignments of the survey participants and then the interview participants.

Survey Demographics

Two-hundred and nineteen (N = 219) J/I teachers were surveyed in total. All of these survey participants teach science at the Grade 4 to 8 level in Ontario. Of the survey participants, 83.87% (n = 182) were female, 15.67% (n = 34) were male, and only one preferred not to specify. The average age was M = 37.1 years. The majority (70.32%, n =

154) of the teachers surveyed reported having between 2 and 15 years of teaching experience. Survey participants represented 49 (68.05%) of the school boards in Ontario. Of the school boards represented, 21 were Catholic and 28 were public. Table 1 provides a breakdown of the characteristics represented by the survey participants including gender, age, years of teaching experience, and academic background.

Current Teaching Assignments

A relatively equal distribution of teachers who teach across Grades 4 to 8 was achieved, as seen in Figure 1. Split grade representation was determined by accounting for each grade within the split in the respective categories (i.e., Gr. 4/5 was accounted for in both the Grade 4 section and the Grade 5 section). When asked about their current teaching assignments, 61.54% (*n* = 128) of survey participants reported that they teach science only to their homeroom class. There was a higher representation of teachers who teach science on rotary (i.e., to multiple classes) at the intermediate level (Grades 7 and 8) than at the junior level (Grades 4–6). Of those surveyed, 40.29% (*n* = 83) reported that they currently teach science to at least one split grade class (Q. 17). The most frequent class size reported was 25 to 29 students (47.12%, *n* = 98). Additionally, of their designated teaching schedules, 50.96% (*n* = 106) survey participants reported that science accounted for less than 20% of their instructional responsibilities.

Interviewee Demographics

Six interviewees were selected from the survey participants who indicated willingness to participate in the second phase of the study. The survey data collected from each of these survey participants were used to calculate aggregate scores based on instructional resource use (Q. 24), and instructional strategy implementation (Q. 28).

Table 1

Characteristics of Junior/Intermediate Teachers in Ontario

Characteristic	Percentage of teachers
Gender	
Female	83.87
Male	15.67
Prefer not to specify	0.46
Age	
≤ 30	26.64
31–40	45.79
41–50	19.16
51–60	6.54
61+	1.87
Years of teaching experience	
< 2 years	10.96
2–5 years	22.37
6–10 years	27.40
11–15 years	20.55
16–20 years	7.31
20–29 years	10.50
≥ 30 years	0.91
Academic background	
B.A.	62.21
B.Sc.	29.49
B.Ed.	87.10
M.Ed.	11.06
Other master’s degree	9.68
Ph.D.	0.46
Other degree or diploma	8.76

Note. The data in the row representing academic backgrounds of surveyed teachers add up to more than 100% because the majority of respondents have more than one degree. These data were gathered from survey questions 1, 2, 4, and 5.

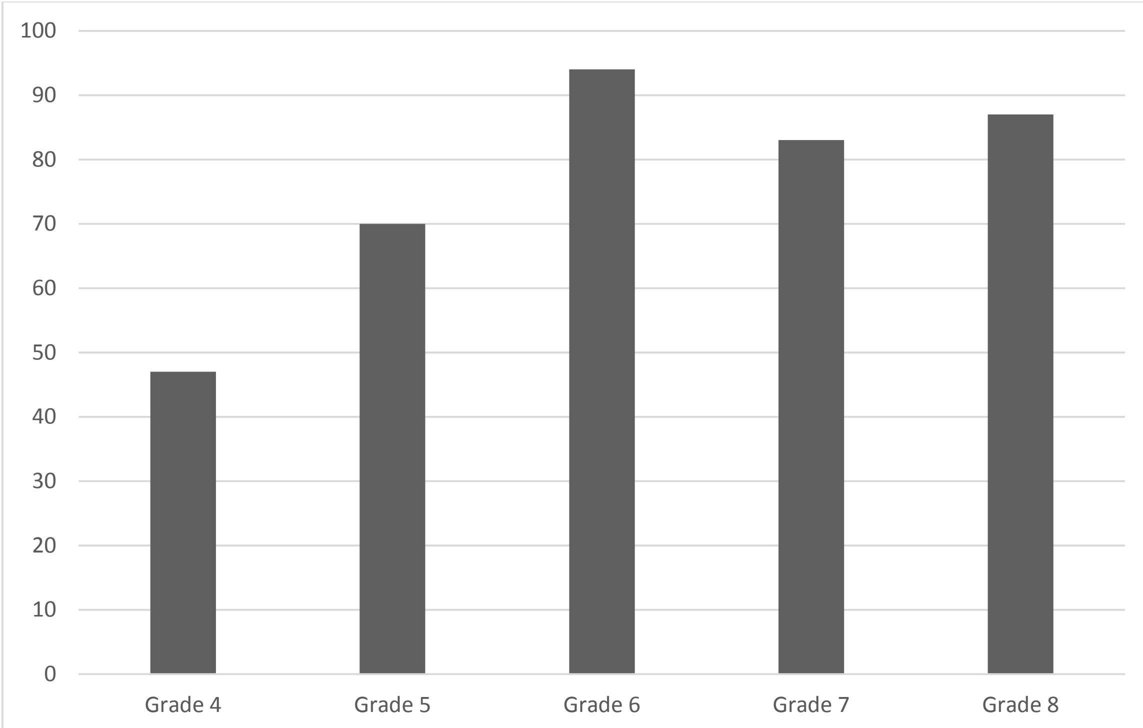

Figure 1. Distribution of survey participants' current grade level teaching assignments. Data were collected from survey question 9. Some survey participants reported teaching more than one class. Split grade teaching experience was accounted for in both grade categories.

Then, these survey participants were organized on a spectrum from low to high aggregated score. The spectrum was then equally divided into low, medium, and high categories to represent frequency of resource use and frequency of instructional strategy implementation. Two interviewees were then selected from each category. The selection of the two interviewees from each category was done so that a wide range in attitudes toward teaching science (Q. 21) and years of teaching experience (Q. 5) across the interviewee population would be achieved.

Table 2 presents interviewee characteristics including the breakdown of gender, academic background, school board, years of teaching experience, grades currently being taught, as well as self-reported comfort level with teaching science. Of the six interviewees, there was an equal representation of teachers with Bachelor of Arts and Bachelor of Science degrees, as well as a range of school board representation, and grade levels being taught.

Academic and Professional Backgrounds

Academic and professional backgrounds were collected from both the survey participants and the interviewees. The academic backgrounds of survey participants were categorized and analyzed based on the number of undergraduate courses they completed in the STEM disciplines and their undergraduate degree completion. The types of science-related PD and amount of time that these teachers have spent on these activities are discussed.

Table 2

Academic and Teaching Characteristics of Interviewees

Interviewee #	Spectrum category	Gender	Academic background	Location of school board	Years of teaching experience	Teaching grade level(s)	Self-reported comfort level with teaching science
1	Medium	F	B.A., M.B.A., B.Ed.	Central	6–10	5/6	Very capable
2	Low	F	B.A., B.Ed.	S/W	20–29	7	Capable
3	High	M	B.Sc., B.Ed.	Southern	11–15	3/4, 5/6	Specialist
4	Low	F	B.Sc., B.Ed.	Eastern	2–5	8 (Rotary)	Specialist
5	High	F	B.Sc., B.Ed.	Central	< 2	7, 8	Capable
6	Medium	F	B.A., B.A., B.Ed.	Central	2–5	4	Very capable

Note. The school boards are all located in the southern region of Ontario.

Academic Background

Four curriculum strands that run throughout Grades 1 to 8 within the *Science and Technology* curriculum: *Understanding Life Systems*; *Understanding Matter and Energy*; *Understanding Structures and Mechanisms*; and *Understanding Earth and Space Systems*. Units in each of these strands correspond to a variety of science content reflecting some STEM disciplines. Question 6 on the survey asked participants to report how many courses they had completed within each of the listed disciplines. Table 3 lists the undergraduate STEM disciplines that each fit within one or more of the four aforementioned curricular strands along with the number of courses survey participants had completed. As can be seen, survey participants had completed the most number of courses in Mathematics, Interdisciplinary Studies (e.g., foundational courses covering a range of science material), and Biology/Life sciences. The three least popular disciplines for course completion were Chemistry, Physics, and Engineering.

In addition to undergraduate course completion, many teachers also completed a science teaching methods course during their preservice teacher education program, 64.35% (*n* = 139). Of those who had completed a science teaching methods course, only 40.25% (*n* = 56) reported that they *agree* or *strongly agree* that this course adequately prepared them to teach science.

The Influence of Academic Background on Confidence Level

Survey participants were asked about the influence of their background knowledge on science instruction (Q. 26). Only 20.30% (*n* = 40) of survey participants reported that their lack of science content knowledge was a limitation to a degree of *quite a lot* to a *great deal*.

Table 3

Junior/Intermediate Science Teachers' University Coursework Completion across Various STEM Disciplines

Discipline	No. of courses: 0	1	2–4	5 or more	Total participants
Interdisciplinary science	86	35	40	23	184
Biology/Life science	95	33	29	42	199
Chemistry	121	11	36	19	187
Physics	129	24	28	4	185
Earth/space science	112	40	27	5	184
Environmental	108	39	23	17	187
Engineering	170	3	2	3	178
Mathematics	76	44	61	20	201

Note. The total participant response counts are not equal due to incomplete survey responses.

The majority (*n* = 4) of the interviewees reported having a moderate confidence level by using the terms like “fairly confident” or “relatively confident.” Interviewee 6’s description of her confidence level with teaching science was also categorized as moderate. She stated:

> On a scale of 1 to 10 probably about a 5, because I do have a wide background, I am not too afraid of trying new things, and as I said, because I know I am lacking in it I do work a little bit harder. I do a lot more research and look at a lot more resources. …I don’t wing it in science, I work really hard and make sure my lessons are put together properly and that they follow some kind of unit plan.

Only Interviewee 3 reported having a high level of confidence by stating, “I feel very confident. It is my favourite thing to teach for sure.” Interviewee 2 expressed the lowest level of confidence, primarily due to her lack of science-related academic backgrounds. When talking about having to teach the *Science and Technology* curriculum she stated, “It’s specific, and I find it kind of intense.” Following this comment, this interviewee was asked if she thought this feeling was connected to the “minimal” science background that she had described in an earlier response, and she agreed that it was.

Several interviewees described knowing that if they had to switch the grade they were teaching that their level of confidence would decline significantly due to having to learn and teach a new set of curriculum expectations. Interviewee 2 stated, “If I had to switch grades and re-build a science program I would definitely not feel confident.” Additionally, two of the three B.Sc. holding interviewees noted that they have specific areas of expertise due to their academic backgrounds and that they do not have a consistent level of confidence across the four science strands. Interviewee 5, who completed mainly biology courses during her undergraduate degree in B.Sc. stated:

> Obviously I feel more confident in certain areas rather than others, so biology and the study of cells and ecosystems which is the Grade 7–8 curriculum, that is something that I am extremely comfortable teaching, whereas systems and structures, which is more physics… I hate physics… so I am a little bit shaky and it is not as fun for me.

In general, the majority of interviewees reported feeling the most confident with the *Understanding Life Systems* strand and the environmental topics within the *Understanding Earth and Space Systems* strand. Overall, the strands that they were most confident with correlated with the courses they completed during their undergraduate degrees.

Survey participants were asked (Q. 36) to report their levels of preparedness with each of the four strands in the *Science and Technology* curriculum. Table 4 presents survey participants' feelings of preparedness for each science and technology strand. *Understanding Life Systems* was rated highest for comfort level among the four strands, whereas *Understanding Structures and Mechanisms* was rated lowest.

Professional Development

Survey participants were asked to report on the amount of time spent participating in science PD experiences in the past 5 years (Q. 9). Figure 2 shows the breakdown, by hours, spent by J/I teachers on science-related PD. Just over half of the survey participants (53.24%, *n* = 115) reported that they had spent a maximum of 2.5 hours on science PD. Importantly, when asked if this PD had a positive influence on their science instruction (Q. 10), 67.13% (*n* = 98) survey respondents reported that they either *agreed* or *strongly agreed* that it did.

Table 4

Junior/Intermediate Teachers' Reported Levels of Preparedness to Teach Each Science Strand

Strand	Response					Total responses
	Not at all	Very little	Somewhat	To a good extent	To a great extent	
Understanding Life Systems	0	4	18	87	71	180
Understanding Structures and Mechanisms	7	13	49	73	38	180
Understanding Matter and Energy	2	10	33	78	57	180
Understanding Earth and Space Systems	1	8	31	91	48	179

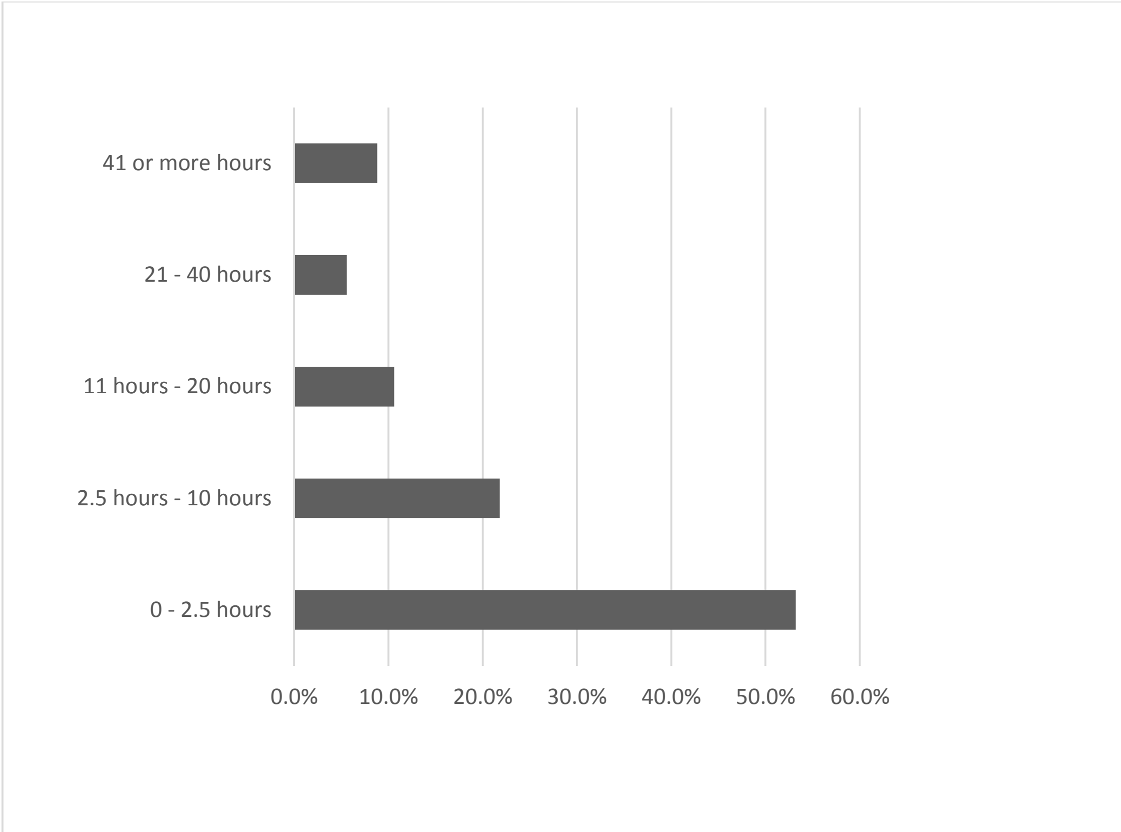

Figure 2. Hours spent by teachers in science professional development activities.

When survey participants were asked if they feel supported by their administration to attend science-related PD workshops (Q. 11), only 41.06% (*n* = 85) reported that they do. Furthermore, 75.00% (*n* = 156) reported that they would like to attend more science-related PD if provided the opportunity (Q. 14).

Interviewees were asked to describe the types of science PD they have attended. However, half of the interviewees had never attended science-related PD. Interviewee 1 completed her *Science and Technology*, Grades 7 and 8 additional qualification specialist, and Interviewees 4 and 6 had attended some science-related in-school PD. Four interviewees mentioned that the majority of PD that they experience as teachers happens in their schools during school district sanctioned PD days.

Several interviewees described the role of support specialists in their school boards and noted that people in this role are the primary facilitators of in-school PD. *Support specialist* is an umbrella term for varying titles like curriculum coach or instructional coach, seen within many school boards. The primary responsibility of support specialists is to work collaboratively with teachers to implement evidence-based instructional strategies for improved student learning (Ontario Ministry of Education, 2007b). Interestingly, none of the interviewees mentioned support specialists providing support for science instruction. When discussing the role of support specialists in relation to PD, Interviewee 4 stated, “they are the coaches for everything [subject areas], so if you don’t have someone who has a particular passion for science then there probably won’t be a lot done around it.” The majority of these interviewees described PD days as being primarily focused on language and mathematics. Two interviewees discussed the pedagogical focus of inquiry and critical thinking during some of their PD, but that these foci were not discussed in the context of science instruction, Interviewee 4 stated:

> The whole thing on inquiry and critical thinking, it fits naturally with science, but the PD is not normally focused on science. It is normally focused more on the literacy and math—and I think that that's what the priority is right now.

Funding was discussed by two interviewees as a limitation to the accessibility of external (outside of the school) science PD opportunities. Interviewee 1 noted that it has been a challenge for her to be granted release time from her classroom to attend science PD. She explained that she has a bunch of students signed up for the *Let's Talk Science* challenge later this year and that she hopes to be able to attend the competition with them. She stated:

> I will probably have to take a personal day to go to the competition. So it would be nice to have school boards that would allow more release time for teachers to do more PD in science and go to these activities.

Although the interviewees reported limited opportunity for science PD during in-school PD sessions, and release time for additional PD was reported as slim, some interviewees reported trying to attend the Saturday portion of the STAO conference—outside of the work-week.

When interviewees were asked about the type of science PD that would best support science teachers, the majority described an experience that would involve the modelling of content-specific hands-on activities that they could do with their students. Two interviewees described wanting to know how to facilitate more kinds of hands-on activities. Interviewee 6 responded to this question by describing her experience with the

STEM kits (a resource provided by her school board). She reported feeling expected to integrate the STEM kit materials across several subject areas and expressed frustration that instructional strategy suggestions had not been provided. She then explained that doing this has been quite difficult for her due to the lack of applicable PD and stated, “I would love to use this stuff but I don’t even know where to start looking at it.” Further, explaining what type of science PD would be most useful to her, “Hands-on, I don’t need to know the theory, I have the curriculum and books, I get all of that. Show me something that I can turn around and do in my classroom the next day.” A couple of interviewees mentioned that the most helpful science PD would be specific to the grade and topic they were teaching at the time. Interviewee 3 stated, “I would like to see kits made for schools, with grade levels and strands provided to the teachers and some training on how to use them.” Interviewee 4 stated:

> It would be great to see more grade specific PD for specific units. If we have noticed that, in general, that teachers are really struggling to teach this unit, maybe soils, it’s a really hard one for them. So let’s have someone come in and do a half day, a whole bunch of little activities, here is how you could make your soil unit more interactive, it would be lovely, I don’t think it’s ever going to happen though—not currently anyway.

Interviewee 3, who reported his capability level as a *specialist* stated, “I think if cost was no option, I think the ultimate professional development would be something where you walk away with a unit’s worth of manipulatives or resources.” Due to the vast number of topics covered across the *Science and Technology* curriculum, the realities of this suggestion being played out would require specific and timely PD opportunities requiring significant time and financial support.

Attitudes of Teachers Toward Teaching Science

When survey participants were asked to report on how capable they feel teaching science (Q. 21), 50.00% (*n* = 103) responded by selecting *I consider myself very capable of teaching science, and enjoy teaching the subject*. Another 13.59% (*n* = 28) indicated that they consider themselves to be *specialists* in the area of science instruction. The remaining 36.41% (*n* = 75) indicated that they would prefer to teach other subjects. Survey participants were also asked (Q. 35-e) to rate whether science instruction was a personal priority. It was surprising to find that 58.56% (*n* = 106) responded between *agree* and *strongly agree*, while 30.39% (*n* = 55) reported that they *neither agreed nor disagreed*. The remainder reported that science was not a personal priority.

Aspects of Science Instruction That Teachers Enjoy

Survey participants were asked to rate themselves on a 5-point Likert scale to indicate the degree to which they enjoy teaching science (Q. 35-a), and secondly, if they feel confident teaching science (Q. 35-c). While 81.77% (*n* = 148) reported that they *agree* to *strongly agree* that they enjoy teaching science, only 71.11% (*n* = 128) reported *agree* to *strongly agree* to feeling confident teaching science. When comparing survey participants with a B.A. to those with a B.Sc., 74.78% of those with a B.A. and 96.43% of those with a B.Sc. reported to enjoy teaching science. Similarly, 60.36% of those with a B.A. and 92.73% of those with a B.Sc. reported feeling confident to teach science.

The interviewees were asked to describe what they enjoy about teaching science. The majority of them explained, first and foremost, they enjoy engaging their students in hands-on experiences, primarily because they enjoy participating in these activities along with their students. The interviewees also reported that they like that science provides their students with an opportunity to exercise their curiosity, which often leads to more complex dialogue in the classroom among the teacher and students. Multiple interviewees also described enjoying the unpredictability of the experiments and research that they do with their classes and that this results in them having the opportunity to learn alongside their students. Interviewee 2 stated:

> I enjoy the, the unpredictability of it, and that's kind of not a theme, but a thing I keep reminding the kids about . . . when we're doing an experiment or things like that, that basically anything can happen and you have to take what happens and learn something from it.

Additionally, Interviewee 6 stated:

> I love the hands on side of science, we talk about needing to engage kids with being able to feel and touch and do things, it's exploring. . . . I think because I know I don't have the background in it. I try a bit harder, and we end up learning together, and the kids know that, it is a lot of fun.

The Priority of Elementary Science Education in Ontario

When the interviewees were asked if they believed that science education is a priority in Ontario, five of six responded "no," while Interviewee 3 stated, "I do, I absolutely do—but I don't know if our curriculum is the best way to approach science." Several interviewees explained that they believe that science is important—if not the most important subject to be teaching but that other educational foci continue to maintain top priority status. Interviewee 4 stated:

> I would like there to be more emphasis on [science], because I think looking forward, and looking at the kind of world the kids are living in now, what they are going to be faced with and the decisions they will have to make as voting citizens. I think that science education and having a good solid foundation—what makes good science verses bad science, is essential. I think it is going to be one of the most important, I mean it is critical thinking . . . they will need to know more than the average person or they will not be able to make informed decisions.

Almost all of the interviewees identified the types of PD provided for them through their schools as reflecting the current educational priorities, and that science was rarely on the agenda. When asked why she believed that language and mathematics were the priorities Interviewee 1 said:

> Well as teachers that is where we are getting all of our PD, and it is what our school is looking at improving in, you know improving EQAO marks, and you know, if you want to go on a PD session, if it is related to language or math you have a much better chance of getting to go to it if it is language or math, but not science.

Additionally, Interviewee 2 noted the difference in grade reporting across subjects as being telltale sign of the educational priorities in Ontario by saying:

> Even if you look at the report cards that we are working on right now—math is five strands, literacy is four, so even just that [reporting], trying to gather evidence for those, it sucks more time from the other subject areas, science is one thing—one little mark, one small little box.

When survey participants were asked if the connection between subject content knowledge and standardized testing influences the prioritization of science education (Q.38) (e.g., EQAO), 66.67% (*n* = 118) responded *no*. Additionally, when survey participants were asked (Q. 26-o) about the limitations on science instruction, 61.42% (*n* = 121) they reported that external examinations or standardized tests were not a limitation. These data do not align with the data gathered from interviewee participants who all reported the strong educational emphasis of language and mathematics in elementary education, which is the only curriculum content used for internal standardized testing in Ontario. When asked why she thought that language and mathematics were the foci, Interviewee 2 responded, “Well I think it is what gets tested on EQAO, you know, so if you’re going to focus on something, it’s got to be something that gets reported on.” Furthermore, when asked how the science curriculum or science instruction should be improved, Interviewee 6 stated:

> It should not be a second tiered subject anymore, it should be equally important to literacy and math … I very much believe the jobs of the future are going to be on the STEM side of the world, and with that in mind, it can’t be a second tiered subject anymore—it has to be given as much importance as language and math.

Supporting Student Needs Through the Science Curriculum

Survey participants were asked if the current *Science and Technology* curriculum sets an educational standard that meets the needs of students (Q. 37). As seen in Figure 3, 54.4% (*n* = 98) of survey participants responded that they either *agreed* or *strongly agreed* that the curriculum does meet the needs of students, while 45.6% (*n* = 82) responded *uncertain* to *strongly disagree*.

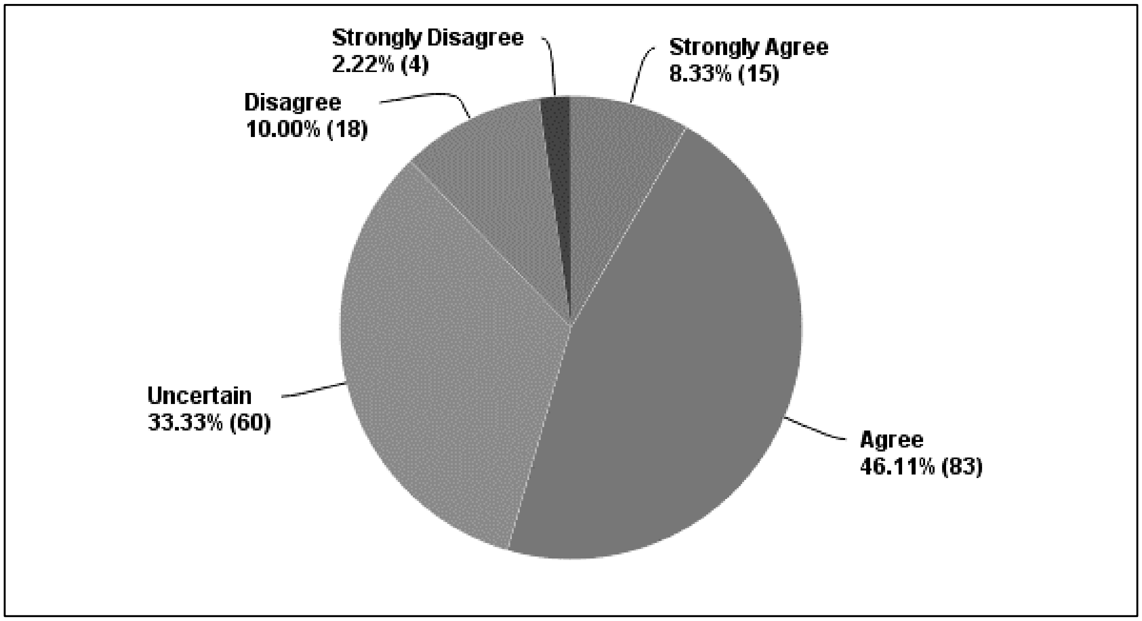

Figure 3. Teachers beliefs about whether or not the current *Ontario Curriculum Grades 1–8 Science and Technology* document (Ontario Ministry of Education, 2007a) sets an educational standard that meets the needs of students.

This survey question (Q. 37) provided the opportunity for participants to add an additional comment about whether or not the *Science and Technology* curriculum sets a standard that meets students' needs. A subset of 48 (n = 48) participants left comments that covered a wide range of topics. These additional comments have been coded with the most frequently coded responses presented. Of this survey participant subset, eight survey participants noted that there were too many strands or expectations for the curriculum to be covered in a way that meets student needs. One survey participant wrote, "I think there are too many strands to study. Added with Social Studies, most teachers seem overwhelmed and offer only a fast overview of topics. The focus becomes quantity over quality. Student interests should guide which strands are delivered." One survey participant noted, "Too many expectations, so little time," while another included, "There is a lot of material expected to be taught in only 100 minutes per week when Language Arts & Math get 200–400 minutes per week. All subjects get equal time in high school." Lastly, the issue of curricular scheduling restrictions was brought up by one participant who reported, "Also [there are] no specified times for teaching... I am now teaching science in 100 min per week it used to be 250 min per week."

Another seven participants from this survey participant subset noted that the curriculum document might provide a set of expectations that could meet student needs but that the resources required to facilitate many of the expectations in the curriculum are not available in their schools. One survey participant expressed this by commenting:

> I agree that the standards prepare a baseline for my students in high school. It is the lack of materials that my school has that prevents full use of the curriculum. Unless I am buying things that are for science experiments and sourcing out

> materials, my students are stuck with a textbook and me (lack of inquiry based experiences). We don't even have enough textbooks. It's a 1:3 [students] per book. Awful.

Along similar lines, another survey participant wrote, "I agree that it can meet the needs of the students IF as teachers we have access to the resources that we need."

Six of the teachers from this survey participant subset discussed the curriculum not meeting the needs of students due to the struggle they face with their students not having the background knowledge to learn about various aspects of the science curriculum. One stated:

> There is a great deal of emphasis lately that has been placed on big ideas, and understandings. We're being guided as "Content Area" educators to investigate extremely large ideas, with very little emphasis being put on the actual content. In my experience the students are coming into my grade 6 classroom with very minimal background knowledge, and inquiry type projects into BIG IDEAS are frustrating for them because they don't have enough basic understanding to move forward.

Another teacher noted that the lack of student background knowledge in science may stem from how they experienced science in the primary grades, "I feel this is why many students are bored and have a poor grasp of science. Too many primary teachers also with no background in science either skipping units altogether, or not teaching them properly."

Nine survey participants from the subset noted that the science curriculum as it is written makes it difficult to meet the needs of students. It was noted by several teachers that the discontinuous nature of the unit strands from grade to grade proved to be a challenge for student comprehension. One participant stated, “I feel it is disjointed from year to year. It sometimes feels like you drop something after a year and the students resume it two years later in a higher grade.” Another noted the challenge that this poses for split grades by saying:

> I feel like it would be good to have curriculum similar to the math curriculum that builds on a concept from the previous year. This way with split grades the topics are more similar and easier to teach side by side.

One of these participants alluded to the idea that the document was not written with the intention of meeting student needs by stating, “If it was intended to meet student need, it would be written in a way that students can understand.”

Lastly, three survey participants from this subset commented that they were not sure if the science curriculum meets the needs of students as it may be outdated and that the evolution of the knowledge in these areas is changing rapidly. With reference to the question in the survey asking participants whether the curriculum sets an educational standard that meets the needs of students, one participant stated, “Science and Technology is such a rapidly growing field it’s hard to predict,” while another said, “Just worried about future careers for young people. It is difficult to keep up with ever changing technology, research and knowledge in the area of science.”

When the entire survey participant group was asked if they believed that science instruction is important for: (a) students’ academic lives, (b) students’ personal lives, or (c) development of future citizens (Q. 39), the responses fell into equal values for each category with a slightly higher value placed on the development of future citizens.

Interviewees were asked if they believed that the current curriculum encouraged students to think about a career in science. Three interview participants stated that they were unsure if it did or not, while the other three stated that the curriculum does but that it needed to be more explicit and accessible to the various realities that students face (e.g., low socioeconomic status). Half of the interviewees also reported that they felt that there were too many curricular expectations for them to add in information about possible careers in science. Interviewee 4 expressed this by saying:

> I think that the curriculum does, though I don't think it is something that gets pushed as much in the classroom, I know that for myself that is one area that I don't do as good of a job as I could—simply because you often run out of time.

Additionally, when Interviewee 4 was talking about how she might go about discussing careers in science with her students she eluded to not being too sure of what modern scientists do. In reference to talking about real-life scientists with her students, she said:

> I don't know that the definition of "What is a scientist?" has changed much. If I asked my kids I'd probably end up having a picture of Albert Einstein on the board, you know, the "What is science and what does it look like in the workplace?" is still not clear.

Science Education Reform

When interview participants were asked about how they think the science curriculum or science instruction could be improved a range of responses were provided. Two interviewees mentioned that they believe more teachers should be teaching with a "hands-on" approach. Interviewee 3 added that this shift would require providing the resources and PD to support teachers' pedagogical development. Three of the interviewees also addressed the change that needs to take place at the ministry level in terms of making science an educational [curricular] priority in our province. Interviewee 6 stated:

> [Science] should not be a second tiered subject anymore, it should be equally important to literacy and math. I very much believe the jobs of the future are going to be on the STEM side of the world, and with that in mind, it can't be a second tiered subject anymore. . . . The jobs end up going elsewhere, I absolutely believe that as well, and I think that should be alarming people at the Ministry of Education, and they should be. I hate to say it, but they should be scrambling to fix it—but they need to fix it correctly . . . but science can't be the poor second cousin that it has been.

Half of the interviewees mentioned that they felt that there was too much to cover in the curriculum and that by reducing the number of expectations, more of the curriculum could be covered well or allow for a more open-ended inquiry approach. Interviewee 5 stated, "There is this balance between wanting them to have an authentic experience and then also needing to cover the curriculum." The other half of the interviewees alluded to the facts that they are not concerned with covering all of the expectations in the curriculum but rather that their priority is to cover a portion of the curriculum well. Interviewee 3 reported, "I think the biggest problem with science education right now is teachers concern themselves too much with trying to cover all of the curriculum instead of covering some of the curriculum really well." Additionally, Interviewee 4 stated, "It would be interesting to see what unit people feel the most confident with—because the unit that you are least comfortable with is usually the unit you don't cover." Lastly, more instructional time for science was suggested as an area for improvement by two interviewees who expressed wanting extra time to more deeply engage their students in inquiry activities. Interviewee 4 shared:

> I would love, like anything, I would love to have more time. … If I had my dream job it would be teaching math and science. …I know in Grade 8 one of the biggest battles I have is rate and ratio because they have done it and they know what it is from a theoretical standpoint but they don't understand it—so then your science teaching turns into trying to re-teach math because they get it if you give them a question, but then when you ask them to use it to try and make decisions and to try and solve a problem they get lost.

Science Instructional Strategies

Survey participants were asked to rate their levels of preparedness for various teaching strategies and several forms of differentiated instruction. Survey participants were also asked to rate how frequently they use various assessment strategies. To acquire more detailed information about science instructional strategies, interviewees were asked to describe one of their typical science lessons and to identify specific challenges with the facilitation of science instruction.

Survey participants were asked to rate the frequency of use of a variety of instructional strategies on a 5-point Likert scale (Q. 25). Figure 4 presents the reported frequency of science instructional strategies used by survey participants. As a whole, these teachers reported that during their science instruction they are most frequently explaining science concepts to their students and engaging students in whole class discussions. Learning about real-life applications to science was reported to occur frequently by 67.18% (n = 131) of survey participants.

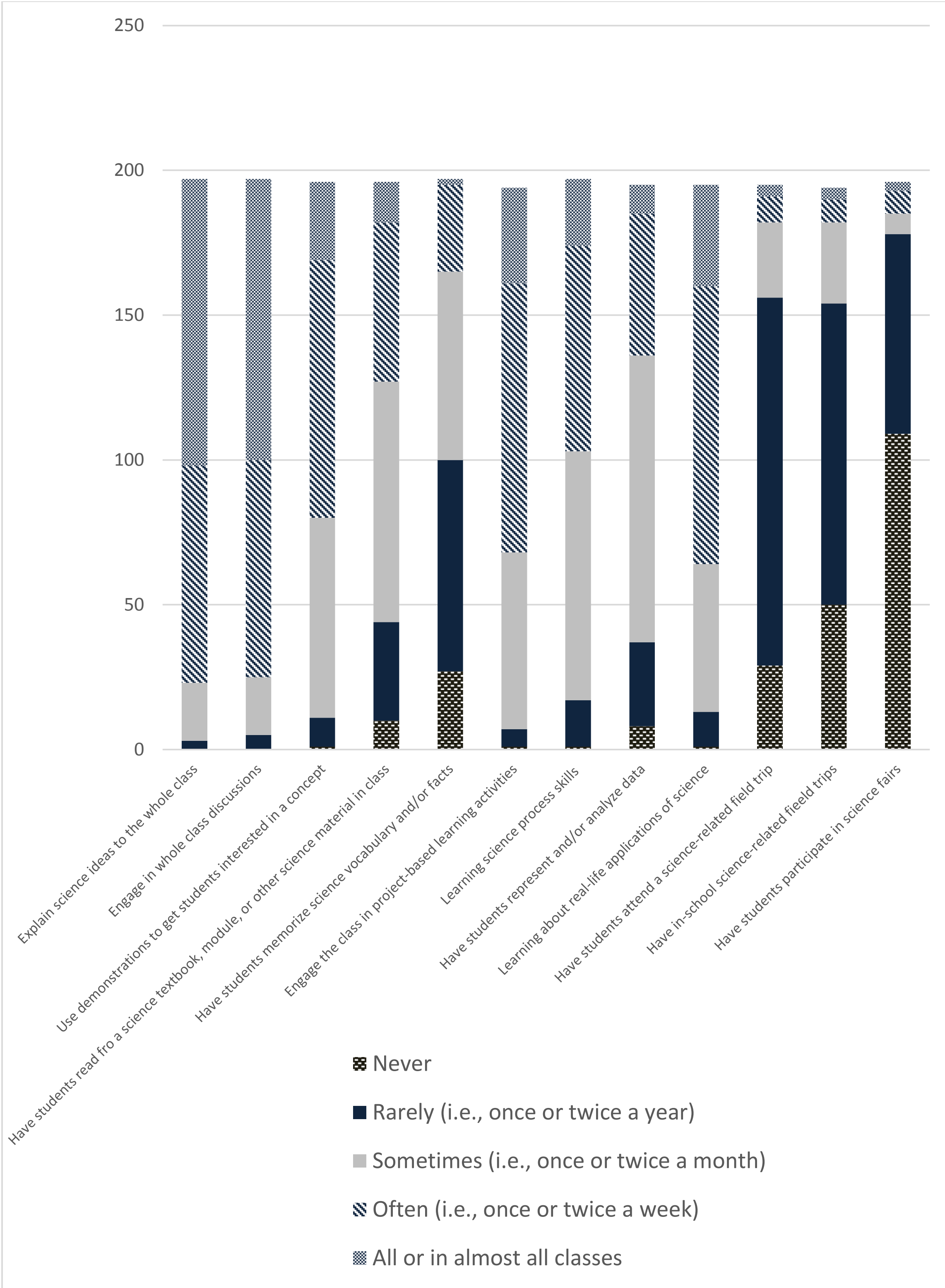

Figure 4. Frequency of science instructional strategy use as reported by science teachers.

Having students participate in project-based learning was reported to happen often (i.e., once or twice a week) by almost half (47.94%, *n* = 93) of the survey participants. However, only 36.04% (*n* = 71) of survey participants reported regularly focusing on the development of science processing skills (e.g., observing, measuring, recording, etc.). One-hundred thirty-eight (70.41%) survey participants reported that their students read science textbooks or other science related texts regularly during science instruction.

Having classes attend science-related field trips inside (e.g., Scientists in the Classroom) or outside of the classroom is not typically a frequent occurrence when compared to other instructional activities, as seen in Figure 4. However, over half of the survey participants did report that their students participate in these types of activities once or twice a year. When asked if their students participate in science fairs, 44.39% (*n* = 87) reported that they do, and from that portion, 5.61% (*n* = 11) indicated that progress on science fair projects is occurring throughout the school year.

Survey participants were asked to report on how frequently they use a variety of student work and performance for assessment purposes (Q. 29). Figure 5 presents the breakdown of type and frequency of tasks used for assessment purposes in science instruction. Student participation was reported as the most frequently used assessment strategy with 76.93% (*n* = 140) of survey participants indicating that they use it regularly (i.e., *often* or *frequently*) to gauge student comprehension. Additionally, formative assessments, including self-evaluations and reflections were reported to be used regularly by 41.53% (*n* = 76). Performance tasks such as model building or student demonstrations were reported to be used regularly by 61.20% (*n* = 112) for assessment purposes, compared to 32.59% (*n* = 59) for tests and/or quizzes.

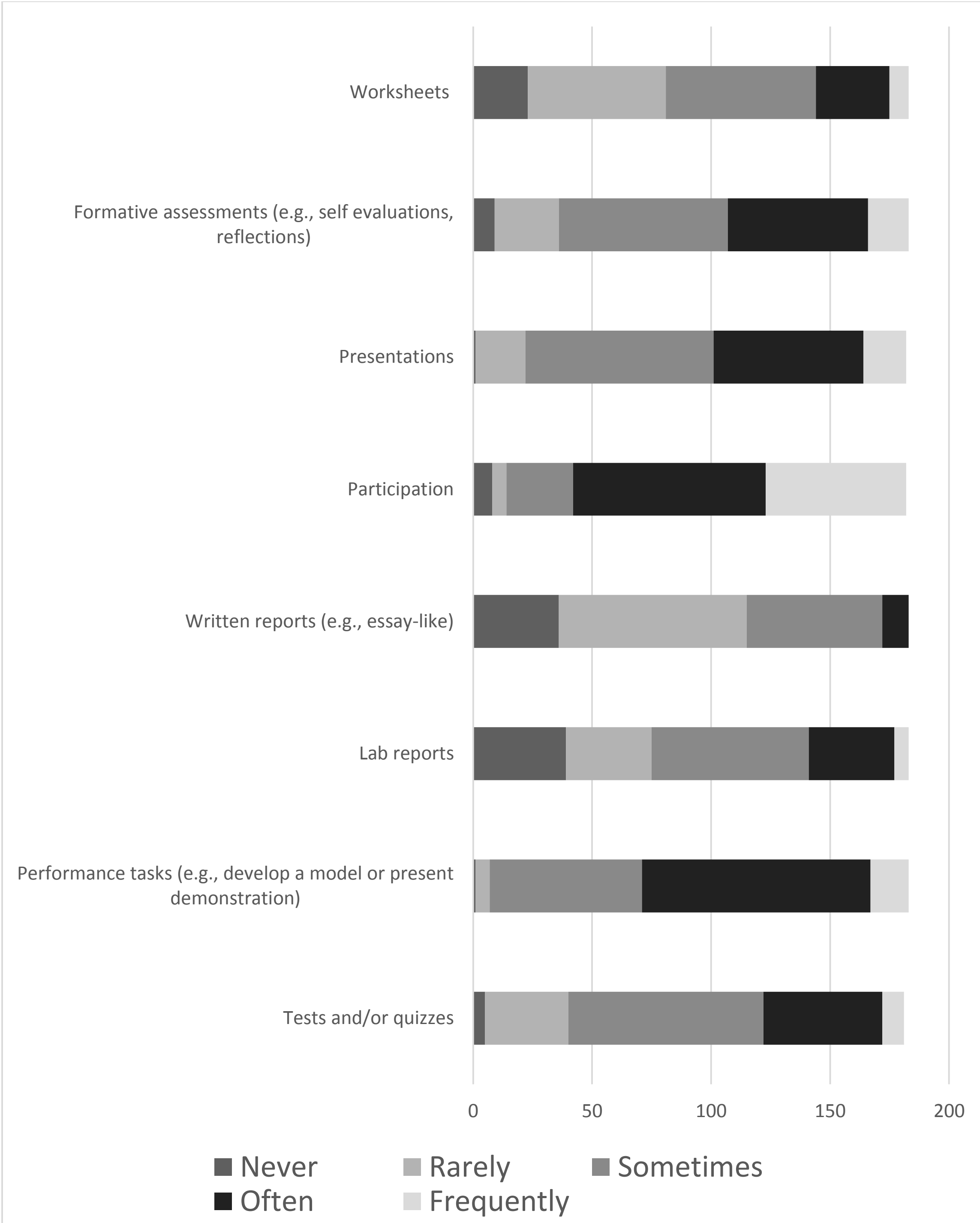

Figure 5. Types and frequency of tasks used for assessment as reported by science teachers.

Survey participants were asked to rate their feelings of preparedness with regards to various forms of differentiated instruction (DI) (Q. 23). As a whole, the survey participants rated themselves as feeling slightly more prepared to teach science to students who have identified learning challenges than to provide enrichment experiences for gifted students. When asked about teaching science to students who are identified as English-Language Learners (ELL), 28.14% (*n* = 56) rated themselves as *not adequately prepared* and 4.52% (*n* = 9) rated themselves as *very well prepared*. Interviewee 5, who currently teaches Grade 8, expressed her challenge with DI by stating:

> My huge challenge this year is how do I make this curriculum accessible to students who are working above grade level, like I have students who are researching glycolysis and anemia and how that affects your cells—we are talking Grade 12 level topics … but also accessible to a student who has lived in Canada for only a couple months and only speaks a little bit of English.

Survey participants were asked about the regularity that they integrate science with or into other subjects on a 5-point Likert scale ranging between *never* and *always* (Q. 22). The majority of participants reported that they *sometimes* (39.50%, *n* = 79) or *often* (44.00%, *n* = 88) integrate science in or with other subjects. Three of six interviewees that teach science on rotary explained that integration was very challenging when teaching to multiple classes. All three said that they would appreciate being able to teach with more curricular flexibility, but that to maintain instructional pace with the other science classes they teach (e.g., homeroom classes could be taught with the integration of other subjects but other classes that the teacher teaches on rotary could not) and to teach within the time allotment provided, integration is very difficult. Interviewee 4 stated:

> So I teach two Grade 8 French immersion classes and I teach them French, geography, history, science and art, but then I also teach a grade 8 English class science, so with my two French classes I can easily integrate science into my language and into my geography fairly easily, but for my English class I only see them for that 100 minutes a week, so I can't do any integration into anything else. There is this constant pull and tug of wanting to go further but not wanting the English kids to get left out of the science experience that the French kids get, do I hold my French kids back so they are in the same place or—it is a constant tug.

Conversely, integration was talked about as a necessity for time management by two interviewees who intentionally overlap curricular expectations as a means to cover more curriculum expectations in a shorter period of time. For example, Interviewee 6 stated, "If we are reading information in science it becomes a literacy thing and we use it as "non-fiction" from a literacy point of view." This is an example of low-level curricular integration. Most of the interviewees also talked about wanting to integrate mathematics with science because their students struggle with understanding the application of mathematical concepts used in science (i.e., rate, ratio, etc.). Although they saw potential for this integration, they also described not feeling very confident with how to effectively facilitate this type of integration. Again, Interviewee 6 stated, "math does some cross-over, that is a weakness of mine, I don't deal well. There could be more for sure, and that gets into that dangerous STEM thing that I would love to do more, but I can't yet."

Scientific Inquiry

Scientific inquiry (SI) is an instructional strategy that is a component of reform-based science education practices. With the intent of gaining understanding about how teachers have interpreted this instructional strategy, they were asked to define SI. One hundred forty-one survey participants responded to the open-ended question, "How do you define scientific inquiry in the context of student learning?" (Q. 27). Interviewees were also asked to define SI. A wide range of responses were collected from the survey and were coded inductively and recursively. Codes were then collapsed into major and minor themes and are presented below.

An Experiential Process of Learning

An experiential process of learning was a major theme identified throughout the definitions collected. SI, an experiential process of learning was included in 58.21% (n = 78) of the responses. Action words or phrases that describe a complex process of learning initiated by either the students or teacher such as "exploration," "investigation," "scientific method," "create," "observe and record," "designing an experiment," and "analyzing data" were coded under this major theme. Furthermore, several definitions for SI outlined the scientific method, which some consider to be a component of SI. For example, one survey participant defined SI the steps in a scientific method (or the reporting of inquiry) from an investigation, as "Purpose, hypothesis, materials, procedure, observations, conclusions." Under this major theme were the two subthemes: teacher guided student learning and student driven (questioning) investigation.

Teacher guided student learning. Teacher guided student learning is a subtheme that was present in 17.91% (n = 24) of the total responses. This theme was given to the responses that indicated that the teacher planned, facilitated, and guided students through a learning process, for example, “Students receive the opportunity to discover scientific concepts through teacher guided activities and research.” Another survey participant acknowledged a desire to move to a more student-directed approach of SI by reporting:

> In Science, inquiry is going to be very directed as I need to get the supplies, and be aware of experiments etc. I would love to do Science Fairs, but our school doesn’t do that but I do a lot of hands on learning for science so feel they get a lot of inquiry/experimentation. It’s just directed more than probably an ideal “inquiry model” should be. But I’m getting there ;).

Student driven investigation. The subtheme, students’ questions drive investigation, was included in 29.85% (n = 40) of the total survey participant responses. This theme was given to segments of responses that indicated that the learning process (e.g., initiating questions, developing procedure, conducing procedure, analyzing results, communicating results, etc.) was primarily driven by students with minimum teacher guidance. Two examples of responses that illustrate this theme are, “The opportunity for students to develop their own questions to drive their learning. To test and experiment theories,” and “Scientific Inquiry allows students the opportunity to formulate a question of interest and pursue the answer through various avenues including research, observation, experimentation, and dialogue with peers and the teacher.”

Asking and Answering Questions

Asking and answering questions was a minor theme that arose from 12.69% (n = 17) of the survey participant responses. A couple examples from the text collected include, “Developing curiosity and a willingness to ask why then attempt to pursue a plausible explanation. Asking questions and seeking answers." "The opportunity for students to generate questions and examine areas of science curricula being studied that interest them," and "Students asking questions about the things around them. Why do the leaves fall? How does the construction of a new house effect the environment? Why do we recycle? Etc." These definitions and responses describe an inquiry about scientific material rather than a process of investigation.

Student Interest

Student interest was identified as a minor theme in 13.43% (n = 18) of the responses. The survey participant responses that were categorized under this theme ranged from simply having students learn about what they are interested in, or curious about, to incorporating student interest into scientific investigations. Some examples of responses that focused solely on student interest included, "Kids deciding what is important for them to learn about," "Let kids learn what they are interested in," and "Students taking an interest in one topic that is being studied and digging deeper into the topic to find out more." An example of a response that describes SI as incorporating student interest within scientific investigations is:

> Scientific inquiry in student learning means that students determine what they are interested in learning. Students are given a big idea, they then must create inquiry questions to investigate and research. Inquiry is student-centered meaning that investigations and instructions directly relate to what the students are interested in learning about.

Real-World Connections

The last minor theme identified was real-world connections. This theme appeared in (n = 12) of the responses. Although SI is a pedagogical strategy the value of incorporating real-world connections for student learning in science appeared frequently in survey participants' definitions of SI. Several survey participants noted that it is important that students are able to extend their learning in science beyond the classroom. Survey responses that were categorized under the theme real-world connections ranged from, "Exploring the natural world around us" to "Being able to connect real-life applications/examples to experiments/discussions done in class. Being able to approach the 'how' and 'why' and justify their responses" and:

> Scientific inquiry is the ability to logically examine an event in the world and what may have caused it, what we could have done to prevent it/change the situation, and the expected outcome of that event based off of facts and theories of science.

These responses, among others categorized under this theme, highlight the importance of allowing opportunities for student learning in science to be connected and applied to their lives outside of the classroom.

Scientific Inquiry Definitions Coded for Four-Level Continuum

The same responses from the survey question (Q. 27) that asked participants to define SI were then deductively coded based on Banchi and Bell's (2008) four-level continuum of inquiry. This coding process was done to see how many responses aligned with an accepted framework that describes the various levels of SI instruction models. Banchi and Bell's continuum of SI levels are: Level 1 (Confirmation Inquiry); Level 2 (Structured Inquiry); Level 3 (Guided Inquiry); and Level 4 (Open Inquiry). One-hundred forty-one SI responses were analyzed from this survey question to see how many aligned with each of the four levels of inquiry. Of the total number of responses, 49 (34.75%) were coded as one of the four levels. The remainder of the responses did not provide a description for SI that aligned with any of the four levels within this continuum. Table 5 shows that of these 49 responses, 11 responses described Level 1 (Confirmation Inquiry), eight responses described Level 2 (Structured Inquiry), six responses described Level 3 (Guided Inquiry), and 24 responses described Level 4 (Open Inquiry). Examples of responses that described each of the four levels of SI are also provided.

When interviewees were asked to describe how they incorporate SI into their science instruction, three discussed the implementation of SI in their science instruction as primarily involving question asking and answering. One interviewee described a guided project she developed for her students, and another described using the scientific method and noted that charting and graphing would be involved. Only two interviewees described using SI as a method for teaching scientific process skills involving problem solving. While Banchi and Bell's (2008) Level Four (Open Inquiry) stage was the most frequently defined by survey participants, none described facilitating this type of inquiry with their students. These results may indicate a rhetoric-practice gap with regards to the discrepancy between the understood SI theory and actual implementation.

Challenges With Scientific Inquiry

When responding to the survey question (Q. 27) that asked participants to define SI there were several participants who responded by sharing their challenges with SI in the context of instruction rather than providing a definition. When referring to SI, one survey participant identified time as a limitation to SI by saying, "a beautiful idea but one that is extremely hard to do in a meaningful way as there is no time."

Table 5

Survey Participants' SI Definitions Coded for Banchi and Bell's (2008) Levels of Inquiry

Code	Frequency (total 141)	Example definition (from survey or interview)
Level 1: Confirmation Inquiry	11	- "The students should have an opportunity to test theories through experimentation and observe results." - "Presenting a lab and letting students do an experiment to understand a new concept and activating prior knowledge."
Level 2: Structured Inquiry	8	- "We are using the 'drive method' in our board. We demonstrate the activity, the students replicate it then they investigate, pick a new variable that they want to change and then evaluate what they have learned from the process. It is very effective." - "Scientific inquiry is the opportunity to challenge students with a problem and have them work through the standard inquiry model as they solve the problem."
Level 3: Guided Inquiry	6	- "By posing a question and having the students develop a hypothesis then a procedure to test it, and the coming up with a conclusion based on the data they've gathered." - "Having students create based on their knowledge and understanding of concepts after having done experiments and had discussions (example create a thermos that will maintain a heat of ____for ten minutes and explain how you've used convection/conduction etc. to influence design)"
Level 4: Open Inquiry	24	- "Allowing students to generate their own interests within the content area, then allowing them to investigate and demonstrate their learning in a multitude of ways. Further, they can investigate by creating questions, and a hypothesis, create and experiment to test their hypothesis, describe the test results and a conclusion." - "Scientific inquiry is a process where ideas are formed, tested, observed, challenged, and re-developed based on reason and evidence-based experience. Inquiry allows students to hypothesize, prepare, experiment, observe, conclude and then apply process to new ideas from what they experienced, which goes deeper than definitions, concepts, applications in the real-world and then pedagogically moving on."

Note. Only 49 participants' responses are accounted for in this chart because not all responses provided a description of SI that aligned with the definitions provided by Banchi and Bell (2008).

One of several survey participants who expressed not knowing how to define SI said, “Good question. Asking a question?!? That they want to know more about? Not really sure.” Another survey participant acknowledged a lack of background knowledge as a limitation for SI by saying, “Difficult to manage when I don’t have the content knowledge to guide them effectively.” Additional limitations to SI were outlined by one survey participant who said:

> Scientific inquiry is too often used in the classroom as ‘following a recipe’ (e.g., a list of steps) rather than a true investigation based on curiosity. I think that teachers with adequate science training do see the value in a more authentic inquiry. However, lack of quality and quantity of resources and equipment, in addition to a physical environment that is not conducive to experimentation, holds us back.

When asked about facilitating SI, several interviewees also spoke of the challenges that arise. Interviewee 4 reported that she recognizes a lack of science content knowledge for many teachers as being a significant limitation to SI. She said that because she does have a fair degree of science content knowledge she recognizes the advantage of the instructional flexibility that she has, but that many people do not have this advantage and as a result have a lot of difficulty. While discussing her facilitation of inquiry she stated:

> I think being a specialist allows a certain level of spontaneity. You might start off your lesson and your intent of your lesson is to get from point A to point B but along the way, really a question comes up and all of a sudden you find yourself at point F or G.

Interviewee 3 explained that one of the challenges with teaching science through inquiry activities is the additional preparation required. Not only do teachers have to find or design an appropriate learning activity for their students they also have to gather and prepare all of the materials as well. When describing this reality he stated:

> When your teaching day ends and you think "Aw man, I'm teaching viscosity tomorrow, I've got to go out and buy seven different liquids of different viscosities," buy it, charge it back, bill it. People shut down and they don't do it.

An additional note about SI was brought about by Interviewee 2 who reported that she, as an intermediate teacher, hears from Grades 9 and 10 teachers that students are not arriving at high school equipped with the necessary skills required to carry out scientific processes including SI. She said that it is for that reason that her school is trying to better meet these student needs; however, these plans have been slow to develop.

Resources and Supports Available

The availability of materials and equipment has a significant impact on the types of science instruction that can be facilitated by teachers. Additionally, human supports like co-planning with colleagues and administrative supports (i.e., principals, vice principals) can offer new ideas, encouragement, and opportunities for instructional reflection.

Resource Use and Availability

Survey participants were asked about the frequency of resource use for the development and planning of science instruction (Q. 24). Responses for the frequency of resource use were collected on a 5-point Likert scale with the anchors range between *never* and *almost every class*. As seen in Figure 6, a large portion of these teachers are developing their own lessons and using internet or other computer-based sources to develop these lessons.

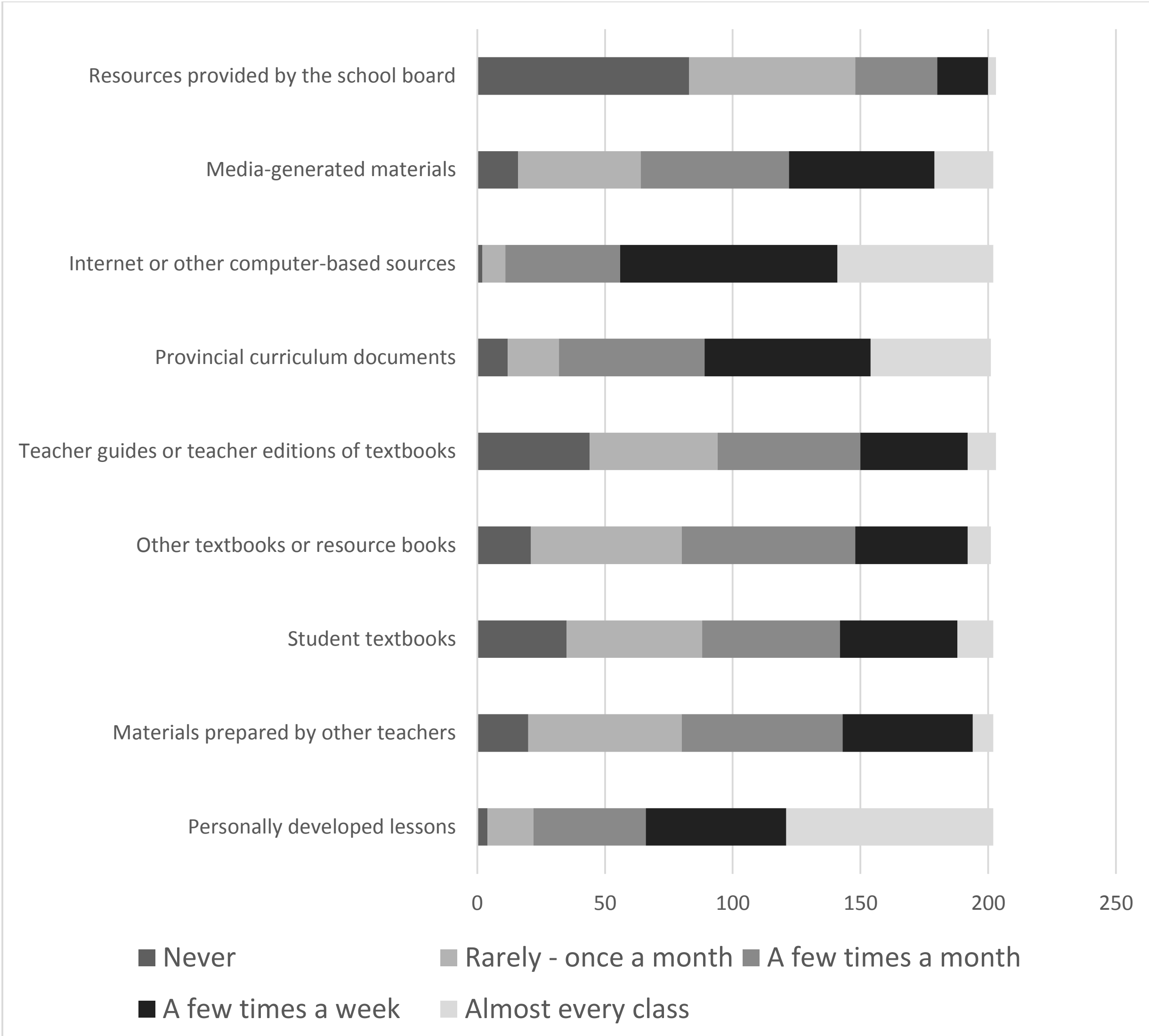

Figure 6. Frequency of resource use for the development of science instruction.

Resources provided by school boards and both teacher and student versions of textbooks were reported as being used least frequently for lesson planning. Several interviewees did comment that they either did not have access to textbooks in their school or that the textbooks were simply not of great quality. Interviewee 2 stated, “We have some textbooks, they are not that great.” Additionally, when talking about the resources available to her, Interviewee 4 stated, “We don’t have textbooks though, well I have a single copy of two different textbooks.”

Survey participants were also asked to report on the availability of resources for their students during science instruction (Q. 31). Responses for resource availability for small group (i.e., 3–4 students) use were collected on a 3-point Likert scale with the three anchors: *at least one per group located in your classroom*, *at least one per group upon request of in another room*, and *do not have one per group available*. As seen in Figure 7, technological devices such as calculators, personal devices, and hand-held devices were reported to be most available for science instruction. The availability of internet access was rated as available to students within the classroom by only 58.66% of respondents. Classroom response systems and virtual learning resources for science (e.g., access to interactive virtual experiment websites) were reported to be the least available for instruction.

Survey participants were asked about the various limitations they face with science instruction (Q. 26). As seen in Figure 8, a shortage of materials and equipment was reported to be the biggest limitation on science instruction as 63.59% (n = 126) reported that a lack of these resources was a limitation to a degree of *quite a lot* to *a* *great deal*. Inadequate physical facilities (e.g., lab benches, sinks, electrical outlets, etc.) was reported to be the second greatest limitation on science instruction with 51.27% (*n* = 101) reporting that the setup of their classrooms was a limitation to a degree of *quite a lot* to *a great deal*. Shortage of computer hardware or software was reported as the third greatest limitation, followed by large class size, disruptive students, limits on survey respondents' background knowledge, and, uninterested students. The two least limiting factors on science instruction, as reported by survey participants was pressure from parents and external or standardized tests.

Interview participants were also asked about the types of equipment and resources available to them as science teachers. A significant range in equipment and resource availability was described by the interviewees from each school board. Interviewee 3 stated that he has worked in six different schools within the same board and has never had the same amount or types of resources available to him. This same interviewee said that although he has typically been assigned to teach science on rotary he has never had a sink or lab benches in his classroom while other interviewees explained that their classrooms are specifically designed for science instruction with lab sinks, lab benches, adequate electrical outlets, and cupboards for science equipment—whether they take advantage of them or not. In contrast, Interviewee 4, who teaches in a science lab classroom explained that she also has access to an annual $500 budget for science materials alone.

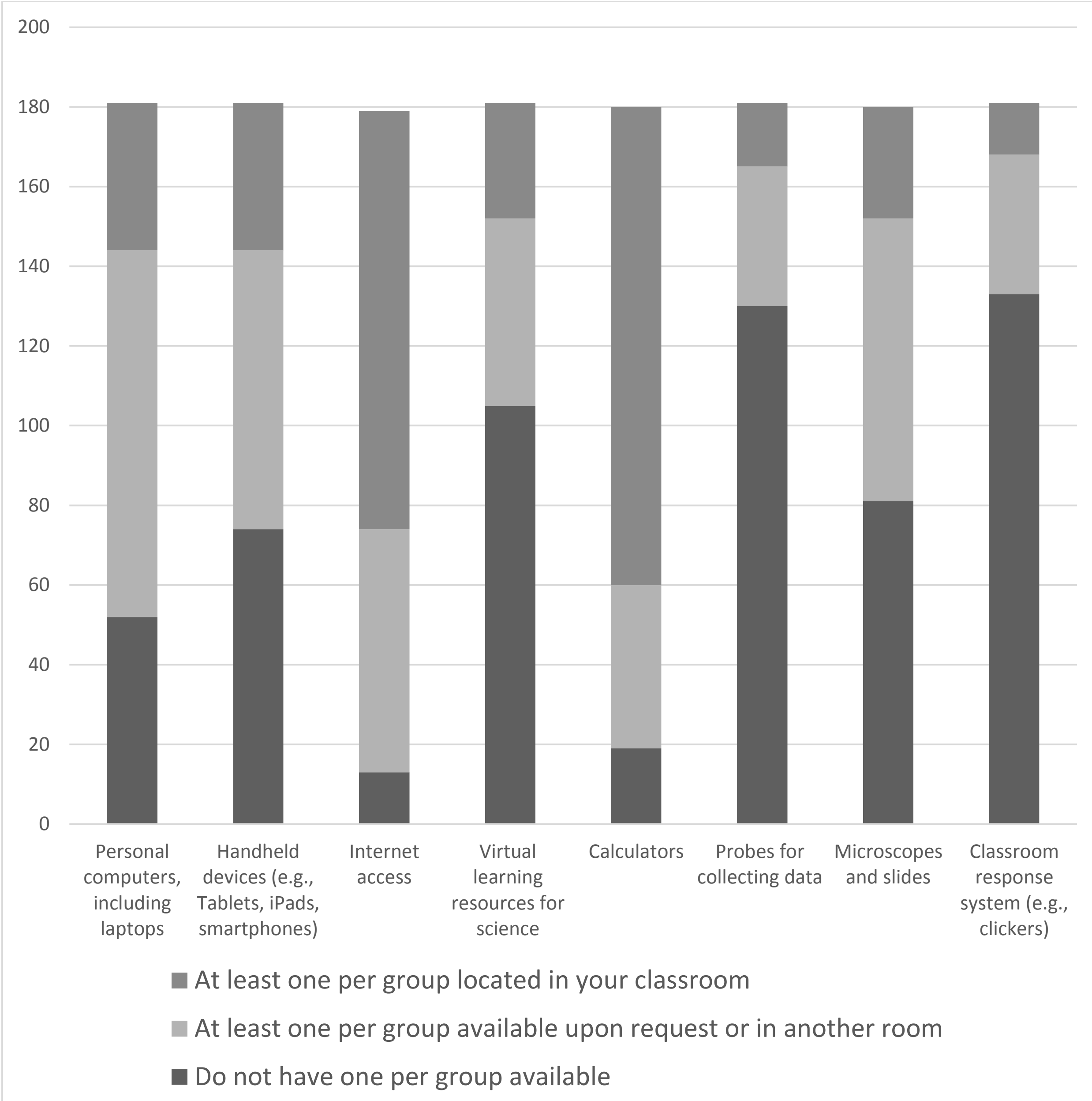

Figure 7. Availability of resources for science instruction based on one unit per small group (3–4 students).

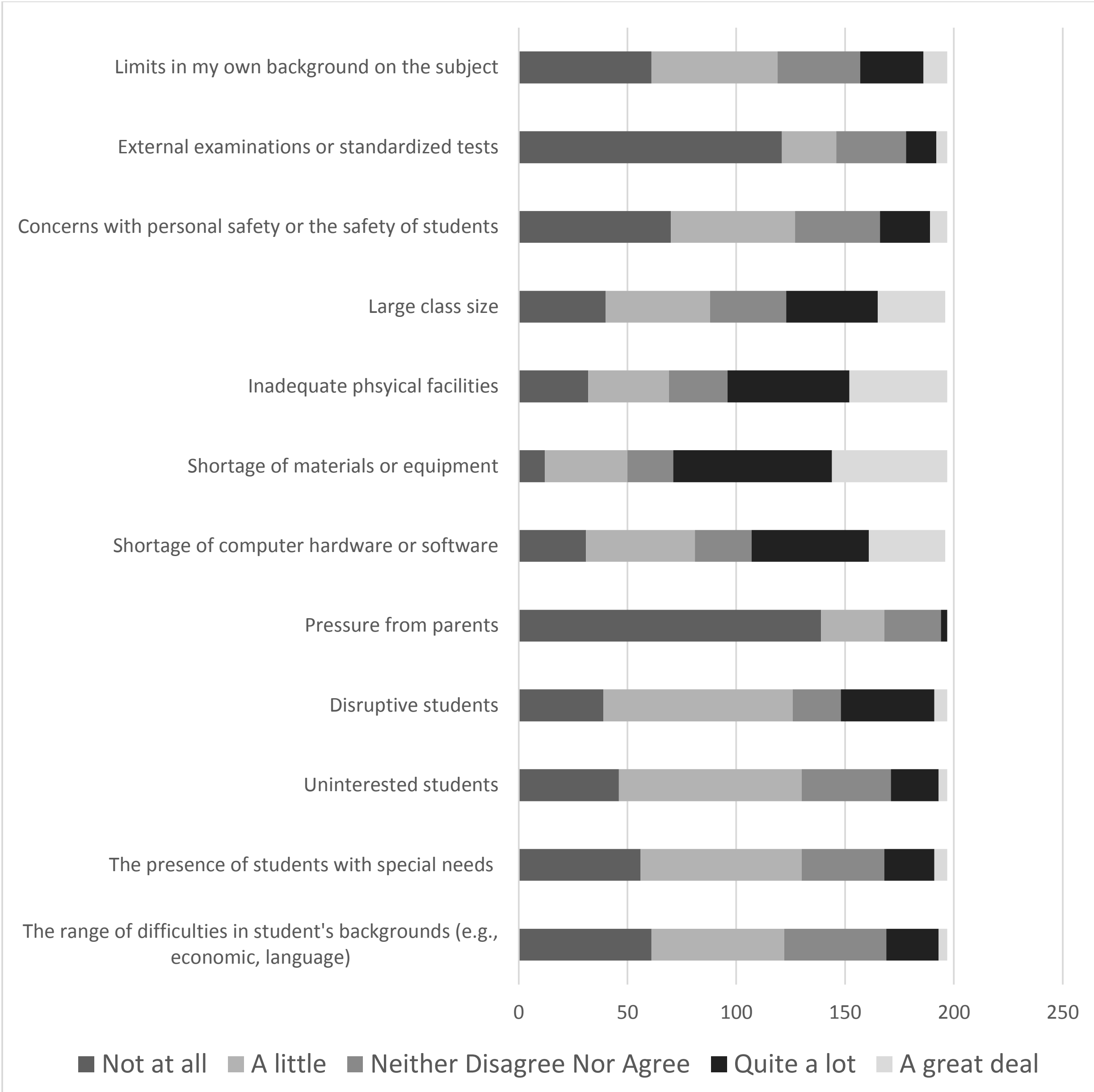

Figure 8. Science teachers' reported degree of various factors as limitations on their science instruction.

Survey participants were asked how comfortable they feel incorporating technology into their science instruction. Figure 9 shows the results from a 4-point Likert scale ranging between *not comfortable at all* to *very comfortable*. Fifty percent of these survey participants reported that they feel *very comfortable* integrating technology into their science instruction. When interviewees were asked about the resources they consider to be most valuable to their science instruction, four interviewees mentioned various technologies. These technologies included: projectors, laptops, online material, document cameras, iPads, and Smart boards. Interviewee 3 did note that while these technologies were of a significant resource for science instruction, they were beneficial for instruction at large. Interviewee 5 teaches at a school where all of the students get their own iPad as part of a board pilot project. She stated, "The fact that my students have their own iPads is really awesome, they can do their own research and they can share their learning in all different ways."

Interviewees were asked to describe the response they would get from their administration if they requested extra funding for science materials. The general consensus was that, small consumable items would make the budget cut but that "large ticket items" such as microscopes, robotics kits, or other equipment would be out of the question. Interviewee 6 responded to this question by saying, "if I was just to say 'I'd like to get some flashlights because I am doing light and sound' it would be like… 'Well can't you just use what we have?' That is the honest truth. . . . Again, science comes *after* [emphasis added] literacy and numeracy, and our budgets are stretched to the breaking point as it is … we are told that pretty much daily."

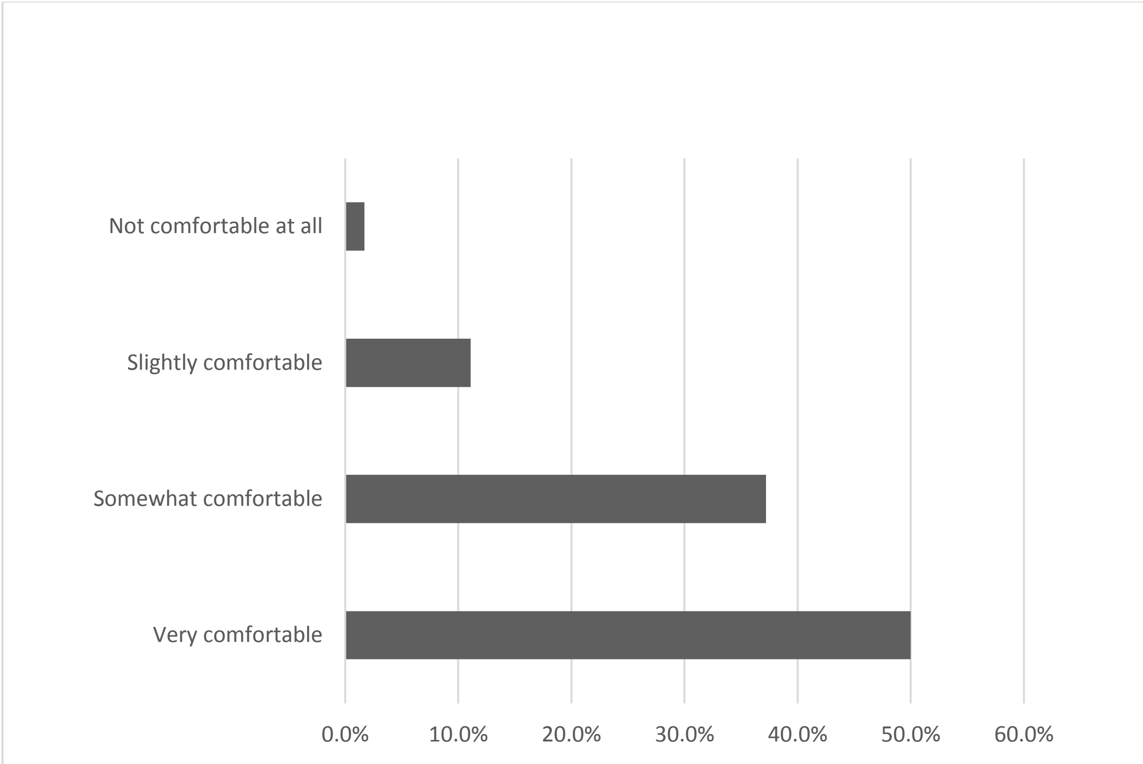

Figure 9. Comfort level of science teachers to incorporate technology into their science instruction.

However, three interviewees also mentioned receiving high-value items like STEM kits, Lego robotics kits, and Lego Wedo kits from their administration as part of various board-wide initiatives. Interviewee 6 reported a high level of frustration with the expectations set out for her to use these materials with very little training on how to incorporate them into their science instruction. This interviewee stated:

> We have these brilliant STEM kits they are gorgeous they are colourful, they have all of these tools in them, um, but, nobody knows what to do with them. And this is where it gets frustrating. When we ask, "Is there one Grade 4 lesson plan?" And we get, "Oh no, we don't want to give you lesson plans because we don't want to restrict you, we want you to explore." . . . I would love to use this stuff but I don't even know where to start looking at it. I guess that is the frustration with it.

Interviewee 6 also described her love for the science kits that she can rent from the school board. She appreciates the starting point that such kits provide and mentioned that she has used them for many years and is now comfortable with modifying the suggested lesson plans because she has learned how to best adjust the lessons to her students. When asked if these kits were one of the resources that have been most valuable to her she responded by saying, "Yes, absolutely. It sounds lazy, but somebody has done the leg work for me. It tells you 'here is what you can use for light and sound, here is what you can do for habitats,' you know." Other interviewees mentioned the availability of these resources in their school board but said had not looked into them.

With respect to materials already present in the schools, three interviewees mentioned the challenge of sharing these resources with multiple classes as they quickly become disorganized, messy, or lost with no central storage or organized sense of accountability to return the resources in the state they were lent out. Interviewee 5 stated:

> I am sure there are a lot more resources available to me than I am even aware of, I just can't find them, which is the unfortunate part. . . . For structures and stuff we have Lego robotics and I have a whole bunch of kinetics kits. But again it is stuff that kids have rummaged around in and they have not been kept organized, it is a nightmare to try and keep it organized.

The interviewees who teach their homeroom classes out of the designated science room in the school noted the additional responsibility of having to keep the materials and equipment organized and catalogued for the other teachers in their schools who also need access to them.

Opportunities for Co-planning

Survey participants were asked how often they have the opportunity to co-plan science instruction with other teachers. Figure 10 shows that 65.75% (*n* = 119) of these survey participants reported that they either *never* or *rarely* have the opportunity to co-plan their science instruction. Interviewees were not explicitly asked about their opportunities to co-plan; however, only Interviewee 1, who teaches junior students, mentioned this as a source of support for her science instruction.

Administrative Support

Survey participants were asked to report how supported they feel by their school-based administrators to facilitate scientific inquiry activities as part of their science instruction (Q. 33). As seen in Figure 11, the largest portion (47.22%, *n* = 85) reported *yes*, they do feel encouraged to implement scientific inquiry. A combined response for *sometimes* and *rarely* feeling supported was reported by 42.78% (*n* = 77). Lastly, 10.00% (*n* = 18) reported that they *never* feel this type of support.

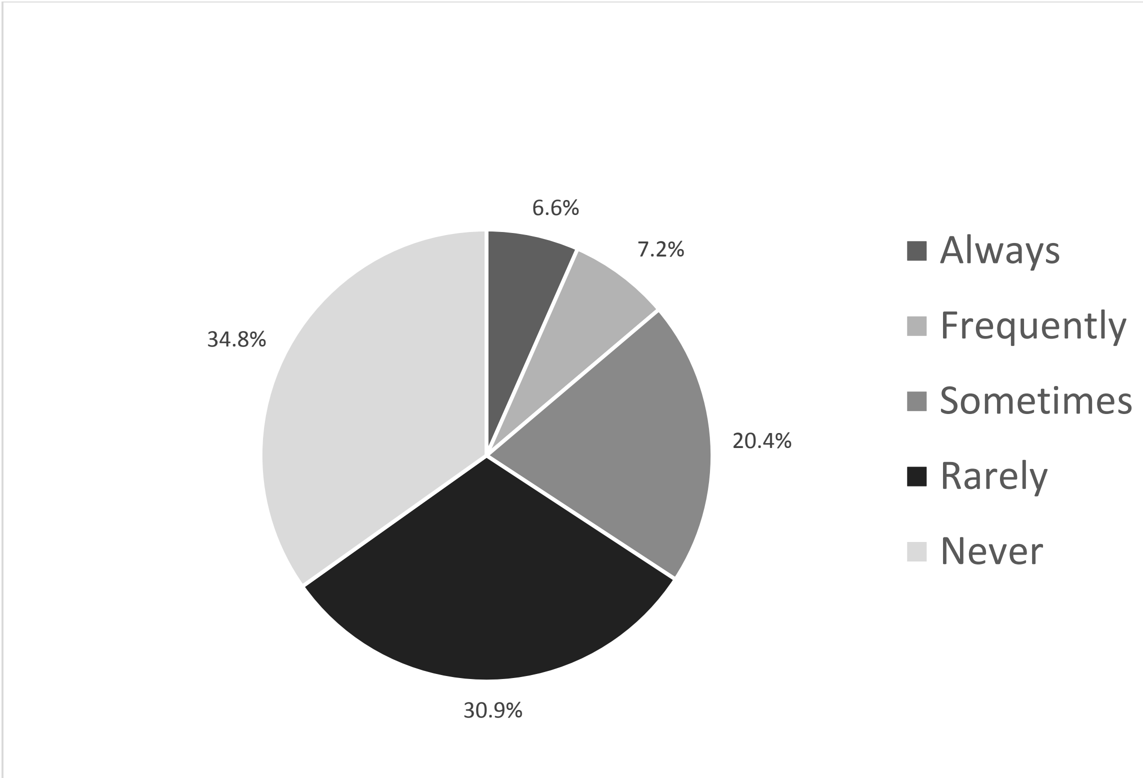

Figure 10. Frequency of opportunities to co-plan science instruction with other teachers.

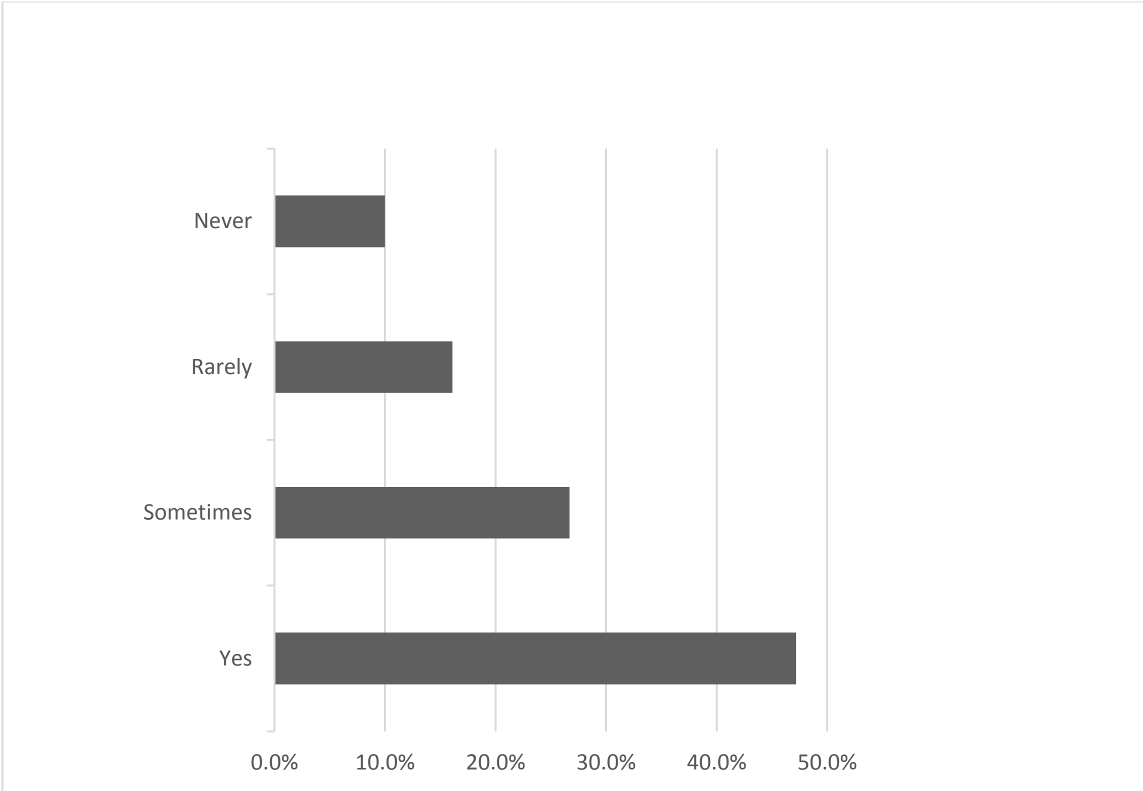

Figure 11. Science teachers' feelings of administrative support of implementing inquiry into science instruction.

Interviewees were asked how they would describe the support they receive from their administration with regard to teaching science in general. Two of the six interviewees stated that they do feel supported by their administration; however, Interviewee 3 noted that he believes the degree of support he receives is atypical when compared to his past teaching experiences and stories from colleagues. Further, when discussing the support he gets to facilitate the types of activities he does, he stated, "I should say, I have a great principal, not all principals would do that." He noted that his principal appreciates the scientific skill development activities he uses by saying, "Yea, and as my principal says, 'You can go ahead and teach knowledge and understanding on Saturday because that's how many people are listening.'" The remaining four interviewees explained that their administration is pretty supportive, but the support they receive is not specific to science instruction. Interviewee 6 reported that the focus of their administration has been language and mathematics while Interviewee 5 noted that she teaches in a low socioeconomic area where "instruction doesn't always get to be the focus because [the administration] is dealing with so many issues involving poverty and mental health."

Additional Resources to Support Science Teachers

Interviewees were asked to list the additional resources that they would like to have for their science instruction. Upon these responses it was clear that there was a divide in the types of additional resources that these teachers would like to have. All of the interviewees who held a B.A. degree noted that they would like to have text resources that provide some sort of "starting point" that is "easily follow-able" and that "brings the curriculum down to a usable level." Interviewee 1 said, "I'd definitely like to have more easily follow-able, not lesson plans, but something to fall back on so that I am not always having to do all my own research and use my own resources.” Conversely, all of the interviewees who held a B.Sc. (3, 4, and 5) reported that they would like to have additional equipment or consumable materials for their hands-on activities. Some examples of these resources include pulleys and gears, consumable items like disposable pipettes, stop watches, magnifying glasses, or additional robotics kits. Both Interviewees 3 and 5 noted that it is the hands-on activities, when they get to use these materials, which they truly develop an understanding of the scientific concepts being taught. Interviewee 3 said that he would like to have pulleys and gears said, “You cannot fully understand forces unless you have force meters, good sets of gears and pulleys and ropes. I have done it four times now, and I struggle with it every time.”

Time for Science Instruction

The impact of both the duration of science instruction within an instructional week, and the frequency of science instruction throughout the academic school year are explored within this section.

Duration

The majority of the survey participants (68.63%, *n* = 140) reported spending an average of 51–150 minutes on science instruction per 5-day instructional timeframe, as depicted in Figure 12. Interviewees most frequently reported a 100 minute per week allotment for science instruction. One-hundred minutes represents 6.7% of weekly instructional time for a typical 1,500-minute instructional week. All interviewees stated that this was not nearly enough time to teach the curriculum well.

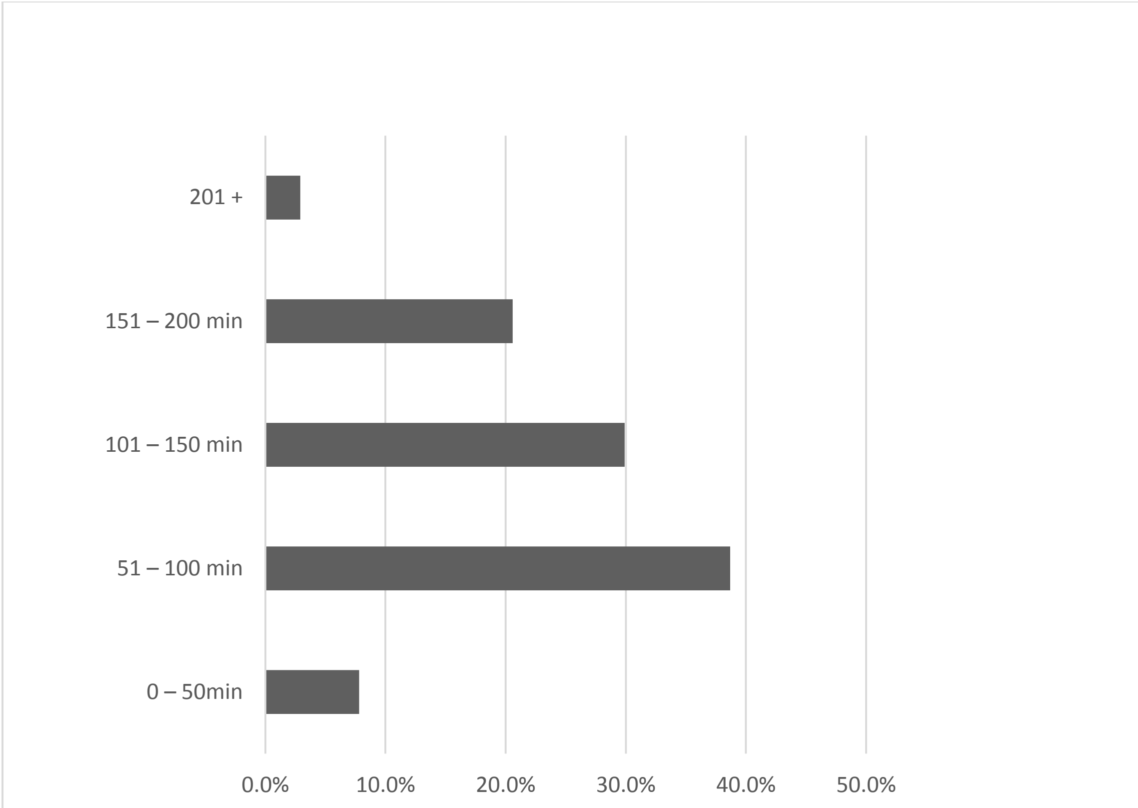

Figure 12. The number of minutes spent on science instruction in an average 5-day instructional cycle.

Specifically, when asked if this time allotment was enough, Interviewee 2 said, "I'd say I don't even hit 75% of what's in that science curriculum." And when discussing her battle with wanting to teach SI strategies but being constrained by prescribed time allotments, Interviewee 4 stated:

> It becomes a real battle to fit things in because if you're just covering the curriculum, well that is easy, it is called, here is the reading and answer the questions, you're "covering the curriculum." But in order to take on the process of scientific exploration and learning to ask questions and text things, it takes a ton of time, so there is a balance of wanting them to have an authentic experience but then also needing to cover the curriculum.

In addition to these challenging timeframes, the survey participants that reported having to teach science to at least one split grade class (40.29%, *n* = 83), would be required to cover the curriculum for both grades in the same amount of time.

Frequency

Of the various frequencies to teach science in the school year, 57.35% (*n* = 117) of survey participants reported that they teach science each week throughout the school year while 22.55% (*n* = 46) reported teaching science for half of these weeks in some form of rotation with another subject. The remaining participants reported teaching science most of the weeks in the school year (15.68%, *n* = 32) or fewer than half of the weeks in the school year (4.41%, *n* = 9).

Interviewees reported being required to be flexible with their instructional timetables to allow for field trips or school events (e.g., assemblies, guest speakers, school concerts) which can result in students having long gaps between their periods of science instruction. Interviewee 4 stated, "If you see them once a week and then there happens to be a field trip or there happens to be an assembly then it's gone and so it becomes a real battle. … I don't think it's enough time." Interviewee 6 explained that she believes students need to engage with science more regularly for purposes of retention and comprehension:

> But 90 minutes, science and math and literacy, it all needs to be a daily thing for them to get it, especially for my little guys in Grade 4—it is 90 minutes because I essentially have two 45 minute periods, I do those two periods and then they don't see science again for days with the way the schedule works out. So literally it's like "remember last week…"; "Do you remember what we were talking about?" I spend the first 10-15 minutes reminding them what we are doing. So you know, no, it doesn't work this way.

Statistical Analyses

The quantitative data collected from this survey were primarily categorical. For this reason a chi-square test for independence was selected. This statistical test was used to look for significant relationships among the two explanatory variables of levels of teaching experience (i.e., novice, experienced, and veteran) (Q. 5), and undergraduate degree (i.e., B.A. or B.Sc.) (Q. 4). The response variables examined included capability level, prioritization of science, time in science PD, and frequency of instruction focused on learning science process skills. Level of teaching experience was selected as an explanatory variable to see if the amount of teaching experience that teachers have influences various aspects of their science teaching practice. Similarly, undergraduate degree was also chosen as an explanatory variable to see if having a B.A. or a B.Sc.

affects teachers' science instruction. The response variables were intentionally selected to assist the researcher with answering the research questions about teacher attitudes, professional experiences, and instructional strategies. Lastly, the results from a one-way chi-square test on the reported amounts of time spent on science instruction in an average week are presented. The levels of teaching experience were broken down into the three categories novice (i.e., less than 2 years to 5 years of teaching experience), experienced (i.e., 6 to 15 years of teaching experience), and veteran (i.e., 16 years and more teaching experience).

When survey participants' reported levels of capability to teach science (Q. 21) were analyzed in regard to their levels of teaching experience the results demonstrated that there was no significant relationship between the two (χ^2 (6, 206) = 14.327, p = 0.7895). Survey participants were also asked to report on whether or not (results grouped into three anchors (a) *agree*, (b) *neutral,* and (c) *disagree*) science instruction was a personal priority to them (Q. 35-e). When these results were analyzed with respect to levels of teaching experience there was also no significant connection found between these two variables (χ^2 (4, 181) = 1.389, p = 0. 8461). The reported amount of time spent by survey participants in science PD (Q. 10) was analyzed with survey participants' levels of teaching experience, and no significant relationship was identified (χ^2 (8, 216) = 14.175, p = 0.0773). Lastly, the frequency of instruction that focused on the development of science process skills (e.g., observing, recording, analyzing) (Q. 25-g) was tested against levels of teaching experience and these variables were also not found to have a significant relationship (χ^2 (8, 197) = 7.507, p = 0.4830). These results indicate that the amount of teaching experience that teachers have likely has little influence on teachers' attitudes toward science, the amount of science PD they pursue, or the instructional strategies they use based on the survey sample.

The undergraduate academic backgrounds of the survey participants were grouped into the categories B.A. and B.Sc. This explanatory variable was selected to see if having a background in science content would have an influence on the attitudes, professional experiences, and teaching strategies of science teachers. When survey participants' reported levels of capability to teach science (Q. 21) were analyzed with their academic backgrounds the relationship was found to be highly significant (χ^2 (3, 186) = 51.498, $p < 0.0001$). Survey participants reported whether or not science instruction was a personal priority (Q. 35-e), and when tested against academic background the relationship was also found to be significant (χ^2 (2, 168) = 15.72, $p = 0.0003$). When time spent in science PD (Q. 10) was tested against academic background there was also a significant connection identified (χ^2 (3, 195) = 14.326, $p = 0.0025$). Interestingly, when testing the data between the frequency of instruction that focuses on science process skills (Q. 25-g) and academic background there was no significant relationship found (χ^2 (4, 182) = 1.235, $p = 0.8723$). Overall, academic background appears to have a strong influence on the attitudes that teachers have about science instruction and the time they spend in science PD; however, not on some instructional strategies.

Lastly, a one-way chi-square goodness-of-fit test was conducted on the data collected regarding the number of minutes that teachers spend on science instruction during an average 5-day academic cycle. The breakdown of this data was presented previously in Figure 12. The timeframes for science instruction in minutes included 0–50 (*n* = 16), 51–100 (*n* = 79), 101–150 (*n* = 61), 151–200 (*n* = 42), and 201+ (*n* = 6). The results demonstrated that the responses were not equally distributed across the five timeframes (χ^2 (4, 204) = 90.559, $p < 0.0001$). The frequency count for the timeframe 51–100 minutes was the highest, indicating that, on average, the majority of teachers are spending 51–100 minutes on science instruction per academic week.

Chapter Summary

This chapter provided an outline of the data and respective analyses involved in this mixed-methods two-phased explanatory investigation. Data were collected from an online survey and follow-up interviews and then analyzed in an effort to explore the current state of Grades 4 to 8 science education in Ontario, but more specifically, to answer the five research questions that addressed teacher attitudes, teacher backgrounds, teaching strategies, teaching resources, and time allotment for science instruction.

Overall, the majority of J/I teachers reported that they enjoy teaching science. About one in five teachers believe that their lack of science content knowledge greatly influences their level of confidence teaching science. The majority of survey participants had experienced very little science PD but three-quarters of survey participants reported that they would like more science PD. When survey participants were asked to define SI, which is currently considered a best-practice in science instruction, only a fifth of the responses were deductively coded in alignment with Banchi and Bell’s (2008) four-level continuum of SI. With regards to planning science instruction, a large majority of these J/I teachers reported that they primarily use Internet-based resources to develop their lessons. A shortage of science materials, equipment, and inadequate physical facilities were reported as the significant limitation on science instruction. The average reported time allotted for science in the instructional schedule was 100 minutes per instructional week. Time allotment for science instruction was identified as a substantial limitation. Lastly, the interviewees consistently noted the educational focus on language and mathematics as the most significant influence on how science is prioritized in their schools. Conversely, over 60% of the survey participants reported that standardized tests like EQAO do not have any instructional implications for teaching science. These opposing data may suggest that many teachers accept language and mathematics as the priority of elementary education and that having to teach science takes time and resources away from these more important subject areas. The results from the inferential statistics performed suggest that academic backgrounds significantly influence teachers' attitudes toward science instruction and the amount of PD they seek, while the level of teaching experience does not.

Chapter 5 will summarize this study and discuss the interpretations of the results as they relate to the current literature previously discussed in chapter 2. The implications of these findings for elementary science will be discussed. Recommendations for curriculum reform, teacher PD, and future research in the area of science education will be made.

CHAPTER FIVE: DISCUSSION

In the most recent 10-year employment growth outlook, Human Resources and Skills Development Canada (Employment and Social Development Canada, 2014) projected that the majority of employment growth will be in STEM-related fields. Additionally, as much as 75% of these new jobs are predicted to be within high-skilled professions. The 2013 Let's Talk Science report states that Ontario alone has already lost $24.3 billion because jobs in these fields are failing to be filled. Unfortunately, these trends are likely to continue in the absence of educational interventions. Issues like persistently declining elementary science TIMSS assessment scores (Fazio & Karrow, 2013), declining student interest in science (Let's Talk Science, 2013), and low science course enrolment in Grades 11 and 12 (Let's Talk Science, 2012) continue to characterize science education in Ontario. Effective science education is required to support upcoming generations with the necessary drive and skill-set to positively impact our society and the environment.

Bressler and Bodzin (2013) and Fitzgerald et al. (2013) identify the middle school grade range as a critical period to foster students' intrinsic interest and self-confidence in science. In fact, research conducted by The Royal Society (2006) report that students' interest in and desire for engagement with science is largely formed by the age of 14. For students to have the best opportunity to develop positive attitudes toward science they need teachers who can effectively facilitate the learning of scientific knowledge, process skills, and attitudes in a meaningful way. Science education research consistently identifies teachers' academic backgrounds as an influential component, or prerequisite, for PCK that supports the effective delivery of science instruction (Appleton, 2007;

Bulunuz et al., 2010; van Driel et al., 1998). However in Ontario, the decisions that science teachers make about how to teach and what to teach depend not only on their academic background, but on a multitude of other factors, including provincial and school board priorities, PD opportunities, support systems, instructional schedules, as well as the accessibility of instructional resources, science equipment and materials.

The purpose of this study was to explore the current state of Grades 4 to 8 science education in Ontario from the perspective of J/I teachers. The methodology for this study was a sequential two-phased mixed methods explanatory design denoted as QUAN (qual) → qual. Data were collected from an online survey and follow-up interviews. The online survey was posted on teacher forums (e.g., STAO Blog) and sent out through the listservs of various educational organizations (e.g., STAO and Youth University). The survey was distributed in this manner in order to attain respondents from across Ontario (N = 219).

Six interviewees were selected from the survey participant population to represent maximum variation across instructional strategies, resource use, reported level of capability to teach science, and years of teaching experience. Member checks of interview transcripts were conducted with each interviewee to ensure accuracy. The research questions that guided this study were:

- What attitudes do J/I teachers have toward teaching science?
- What science-related academic and professional experiences do J/I science teachers have?
- What teaching strategies are J/I science teachers currently using to teach science?
- What support resources are available to teach science in elementary schools?
- How much instructional time is allocated for science in elementary schools?

The collection of quantitative and qualitative data was followed by separate data analysis with findings integrated throughout the interpretation and discussion sections of the thesis. Data analyses were performed on the quantitative data from the survey with the descriptive statistical functions offered through the SurveyMonkey software. Descriptive and inferential statistics were also performed using MS Excel. Qualitative data from the survey and the interviews were inductively coded. Codes were collapsed into major and minor themes. A subset of the qualitative data that addressed SI was also coded a priori using a model of SI.

This chapter discusses the results of this study in relation to the guiding research questions and current related literature. Recommendations for elementary science education are provided. Lastly, the implications for J/I science educators, as well as the implications for future research in the field of science education are discussed.

Discussion

This section provides an outline and interpretation of the findings from this study interlaced with current literature; which together can be used to provide insight into the current state of Grades 4 to 8 science education in Ontario.

Academic Background

A foundational background in science has been found to assist teachers with helping their students to comprehend science content and to recognize science as a way of thinking and knowing (Fulmer, 2013; Trygstad, Smith, Banilower, & Nelson, 2013). According to the 2012 OCT (2013b) statistical data, only 8.7% of J/I teachers in Ontario have a teachable in science. Having fewer than one in 10 J/I teachers with an academic background in science undeniably impacts how science is taught to Grades 4 to 8 students across the province. Of the survey participants from this study, just under 30% reported having a B.Sc. This percentage is substantially higher than the total J/I population of teachers with a science teachable reported by the OCT. The 2011 TIMSS *Ontario Report* (EQAO, 2011) presents a similar statistic to the findings from this study by reporting that 38% of Grade 8 students in Ontario are taught by a teacher who has an academic background in science. This percentage for Ontario reported in the 2011 TIMSS report is considerably lower than the percentage of Grade 8 teachers in Alberta (56%) and Quebec (69%) with an academic background in science, as well as the international average (79%).

The results from the statistical analyses performed on the survey data demonstrate that there is a significant relationship between academic background (i.e., B.A. or B.Sc.) and the reported degree of capability teachers have to teach science as well as the degree to which they view science as a personal priority. Interestingly, there was no significant relationship found between survey participants' years of teaching experience and the reported degree of capability that these teachers have to teach science. The findings from this study indicate that teachers' academic backgrounds have a notable influence on teachers' science instruction and the instructional choices that they make, while their years of teaching experience do not. The 2011 TIMSS *Teacher Preparedness* report adds that teachers' academic preparation is significantly correlated with student achievement (TIMSS & PIRLS, 2011). Furthermore, Darling-Hammond (2000) and Fulmer (2013) also identified teachers' level of science content knowledge as a significant predictor of students' achievement.

According to multiple interviewees, having a B.Sc. does not mean that a teacher's level of confidence with science content and respective instruction is consistent across

Ontario's four *Science and Technology* curricular strands: *Understanding Life Systems*, *Understanding Matter and Energy*, *Understanding Structures and Mechanisms*, and *Understanding Earth and Space Systems*. Interviewees with a B.Sc. reported feeling most confident with the curricular strands that correspond to their undergraduate course work. In alignment with this finding, survey participants who reported taking five or more undergraduate biology courses indicated feeling most comfortable with the *Understanding Life Systems* strand. This study's findings may indicate that even though 8.7% of J/I teachers in Ontario have a teachable in science, they still may not feel fully prepared to teach all the topics in the Ontario elementary *Science and Technology* curriculum.

Interviewees who have a B.Sc. were able to recognize that their uneven content knowledge across curricular strands results in an unequal quality of science instruction across curricular topics. These interviewees expressed confidence to learn more science content and to improve their PCK to increase the overall quality of science their instruction, while interviewees with a B.A. did not. These findings may indicate that teachers with lower levels of science content knowledge may not be aware that their science teaching practices may need improvement. The survey data showed that 28.57% of those with a B.Sc. and only 9.63% of those with a B.A. spent 21 or more hours in science PD over the last 5 years and this difference was found to be statistically significant. Feldman (2000) and Smith (2005) both report that if teachers do not feel discontent with their current teaching methods they will be less likely to seek support to improve their practice. Teachers who recognize areas for growth in their practice and feel that they are capable of making these improvements are much more motivated to seek the support that can help them achieve these desired goals (Sowell et al., 2006).

Professional Experiences

The results from this study indicate that the majority of J/I teachers are not participating in an adequate amount of science PD, especially when compared to the PD they participate in for other subjects. Over half of the survey participants reported that they had experienced a maximum of 2.5 hours of science PD in the last 5 years. Interestingly, three out of four teachers reported that they would like to participate in more science PD if given the opportunity. The desire for more science PD may be an indication of teachers wanting to develop a higher confidence in their science instruction. As explained by the interviewees, the educational priorities of the Ontario Ministry of Education and respective school boards are noticeably emphasized through the duration and frequency of PD focused on language and mathematics. For instance, one interviewee commented that she would easily be granted permission to attend PD if it was related to language or mathematics, but not if the PD was for science. Indeed, the Ontario Ministry of Education explicitly emphasizes their intention to provide PD specifically for language and mathematics in order to increase student achievement in these subject areas (Ontario Ministry of Education, 2011). The deficit of science PD offered to J/I teachers in Ontario speaks volumes about the value that has been assigned to science education. The amount of time that teachers spend on science PD influences the amount of professional learning experiences that can positively impact their attitudes toward science as well as the amount of exposure they have to science reform practices (Lumpe et al., 2012). Time for PD is not the only concern, however; science PD also needs to be effective.

Of the survey participants who had attended some science PD in the last 5 years, about 65% reported that their PD experiences have had a positive impact on their science instruction. When the interviewees were asked about the types of science PD that best support their science instruction the majority described typical PD sessions that focus on how to facilitate pre-developed lessons or prescribed hands-on experiments. The primary challenge with this method is that it may only result in short-term changes as it does not aim at improving the attitudes that teachers bring to their science class (Clarke & Hollingsworth, 2002; Desimone, 2009; Lumpe et al., 2012). These findings may indicate that teachers themselves do not recognize that quick-fix strategies do not necessarily result in lasting improvement. This may also indicate that while teachers may want to participate in more science PD they are not fully aware of the commitment required for the necessary transformation in practice to occur.

The intended purpose of science PD needs to shift from providing one-time-use activities to increasing the attitudes and level of self-efficacy that teachers have for long-lasting improved science instruction (van Aalderen-Smeets et al., 2012). PD experiences designed to improve teacher attitudes toward teaching science and to alter teaching practices are important because they have been known to positively influence student achievement (Lumpe et al., 2012, van Driel, Meirink, van Veen, & Zwart, 2012; Yoon, Duncan, Lee, Scarloss, & Shapley, 2007). Well-designed PD should acknowledge teachers' needs and their expectations so that the facilitated experiences can be structured to cause teachers to become more critically literate of their practice, their potential to impact student learning, and to have opportunities to experience and practice reform-based teaching strategies (Clarke & Hollingsworth, 2002; Saka, 2013; Walma van der Molen & van Aalderen-Smeets, 2013).

Teacher Attitudes

Kirik (2013) states that the quality of science teaching methods courses completed during one's teacher education program has an influence on the attitudes teachers develop toward science instruction. According to the survey results, only about 65% of participants completed a science teaching methods course. Still, only about half of these survey participants agreed that this course adequately prepared them to teach science. The Ontario Ministry of Education mandates that every teacher education program includes a science teaching methods course, however, there are no consistency guidelines for instruction or expectations provided (Ontario Ministry of Education, 2014). The effectiveness of the science teaching methods courses for preservice teachers is very important when considering the lack of science PD being offered to teachers throughout their career. For teachers to develop effective science PCK, they need to experience various methods through which to teach science and they need time to reflect on how their conceptions about science influence their practice (Morrison, 2013).

About 60% of survey participants from this study reported feeling capable to teach science. Similarly, the TIMSS *Ontario Report* presents that 61% of Grade 8 students are taught by teachers who feel "very well" prepared to teach science, yet this compares to 72% of Grade 8 teachers in Alberta, and 71% in Quebec (EQAO, 2011). Perhaps expectedly, self-reported capability to teach science is indicative of the way that teachers teach science and the way students perceive science instruction (Lumpe et al., 2012). Teachers' reported level of capability to teach science is linked to science teaching self-efficacy which has been found to be significantly predictive of students' science achievement (Kirik, 2013; Lumpe et al., 2012). An Ipsos-Reid study conducted in 2010 reported that 70% of Canadian teens agree that their teachers strongly influence how they perceive science and an additional 15% reported that the way their teachers engage them with science is their favourite aspect of science class (Let's Talk Science, 2010). These statistics suggest that teacher attitudes toward science and science instruction influence how students perceive science and the attitudes they develop toward learning science.

When reporting feelings of capability, the other 40% of survey participants indicated having a low attitude toward teaching science by reporting that they do not feel capable and would prefer to teach other subjects. Teachers who feel that they have a lower level of capability to teach science are typically less willing to experiment with reform-based practices like SI, which are known to increase students' desire to engage with science learning (Loukomies et al., 2013). If teachers do not believe that their actions or teaching practices can change students' level of interest or achievement, they are typically less motivated to alter their practice (Sowell et al., 2006). Effectively, teachers who feel less capable to teach science are less likely to implement reform practices (Jones & Carter, 2007), and less likely to positively impact student achievement in science (Jarvis & Pell, 2004).

Eighty percent of survey participants reported that they enjoy teaching science and 71% reported feeling confident to teach science. These results were surprising considering that only about 30% of survey participants have a B.Sc. van Aalderen-Smeets et al. (2012) and others report that teachers' attitudes toward science are particularly important as they have been found to be correlated with the development of students' attitudes toward science. When asked what they enjoy about teaching science, interviewees reported that they appreciate that science provides them with opportunities to engage their students in hands-on activities and to see students using curiosity to drive their learning. These teachers also alluded to enjoying the dialogue and experiences in science where they get to learn alongside their students.

Just under half of the survey participants reported that they are either uncertain or disagree that the current *Science and Technology* curriculum standards meet the needs of students. The additional comments left following this question showed that teachers feel that there are too many expectations to be covered in the current *Science and Technology* curriculum. They also reported that there are not enough resources available to teach science effectively, and that students arrive in their class with a poor level of understanding about science, which they attribute to poor primary science instruction. These comments indicate that teachers believe that successfully meeting the needs of students with respect to science and technology instruction is outside of their control.

The development of teacher attitudes toward any aspect of education is also influenced by the spoken or unspoken priorities of the governing bodies that mandate educational systems. The educational priorities of language and mathematics are not a secret in Ontario. A 2012 EQAO publication titled *The Power of Ontario's Provincial Testing Program* states, "The focused attention on literacy and numeracy—strongly supported by Ontario's provincial testing program—has led to demonstrated improvements in student achievement" (p. 12). The data collected by EQAO since 1996 (EQAO, 2012b) provide strong evidence to demonstrate that extensive academic focus and teacher PD in language and mathematics has a positive correlation with student achievement. With these priorities in mind, it was surprising to learn that about 70% of survey participants believe that standardized tests, like EQAO, have no influence on how science education is prioritized in Ontario. This high statistic may be due to participants misinterpreting the question in the survey. However, it is somewhat understandable when considering the fact that about 90% of survey participants have been teaching for 20 years or less, and may have never experienced working in an education system uninfluenced by EQAO.

A different message was communicated by all of the interviewees, however. All six interviewees explained that language and mathematics are the number one priority in their school boards. When asked by the researcher why they thought this priority stands, the response was that the EQAO assessments test language and mathematics and that these are the scores that are tracked within schools and reported to the public. These opposing data may suggest that many teachers do not recognize that language and mathematics have become a major priority in response to the implementation of EQAO, causing other subjects to be marginalized in return. In fact, one survey participant stated that language and mathematics should be the focus of science education and that there should not be a specific science curriculum. Many teachers may believe that having to teach science takes time, resources, and attention away from being able to meet the student success goals in language and mathematics (Fazio & Karrow, 2013).

Time Available for Science Instruction

The Ontario Ministry of Education suggests, but does not mandate, a 100–120 minute learning block for daily language instruction and a 60–75 minute learning block for daily mathematics instruction (Ontario Ministry of Education, 2009). There is no instructional time recommendation for science. In fact, a specific time allotment for science instruction has not been outlined by educational policy in over 25 years. Without scheduling requirements, school boards are left to independently determine the amount of time their students will spend on each subject. This autonomy permits the relatively large variation in allotted instructional times across subject areas. Top scheduling priority is consistently given to language and mathematics as student achievement scores in these subjects are publically reported by EQAO on an annual basis. Without a system of internal accountability for student achievement in science, there appears to be little reason to make scheduling adjustments. Consequently, the provincial highlights from the Grade 6 EQAO (2015) show an increase in reading and writing scores since 2009, while the TIMSS Ontario science scores have been declining since 2003 (Fazio & Karrow, 2013). Understandably, the scheduling decisions made by school boards indirectly communicate the value ascribed to each subject, including science, to both teachers and students.

Inadequate time was reported by interviewees as one of the greatest limiting factors on science instruction. The majority of survey participants reported spending about 100 minutes on science instruction per week. When considering a typical 1,500-minute instructional week, 100 minutes constitutes only 6.7% of this total time. The range of reported time spent on science instruction by survey participants adds to the understanding of the degree of variation in science instruction across Ontario. Clark and Linn (2003), Lavy (2010), and Blank (2013) found that the amount of instructional time spent on science in the middle school grades has a positive and statistically significant effect on student achievement as determined by large-scale international assessments (e.g., TIMSS).

Survey participants and interviewees alike reported not having enough time to address the entire *Science and Technology* curriculum, while others mentioned concern over not having enough time to engage students with inquiry activities in addition to meeting the curriculum content expectations. If teachers are recognizing that there is not enough time to teach everything in the curriculum, they are inevitably making decisions about which information and skills will be covered. When discussing the time available for science instruction, one interviewee explained that she consistently anticipates having to skip one of the four units each year because she runs out of time, while another mentioned recognizing that whichever unit teachers are least comfortable with is usually the unit that is not covered. Hodson (2011) explains that teachers add, delete, and modify curriculum content to fit the material they are teaching into their current understandings and perceived instructional strengths. If time is a limiting factor on science instruction, it can only be expected that these incidences of instructional manipulation would be exaggerated.

In addition to scheduling decisions made by school boards, teachers have the autonomy to make adjustments to their timetable throughout the instructional day. These decisions often reflect their content knowledge and levels of confidence causing certain subjects to be prioritized over others (Harlen, 1997). Just over 60% of survey participants reported that they lose 20–40+ minutes of science instruction per month due to irregular disruptions or to have students complete tasks for other subjects. Therefore, even if 100 minutes of instructional time is scheduled, less time may actually be utilized for science instruction if teachers do not consider science to be an educational or personal priority.

Science Resources and Equipment

For teachers to be able to facilitate high quality science instruction, adequate facilities, as well as equipment and materials, need to be available. Aside from time, about 65% survey participants reported that the absence of appropriate facilities (e.g., lab benches, sinks, electrical outlets, etc.) and the shortage of necessary equipment (e.g., beakers, hot plates, scales, etc.) cause the greatest limitation on the types of instructional activities they can facilitate in science. Two interviewees mentioned that they were fortunate to teach in newer schools where their classrooms were designed as science labs. One interviewee expressed frustration over the fact that he has taught science on rotary in several schools and has never even had a sink in his classroom while another discussed how fortunate she felt to have an annual $500 science budget. The range in available resources is another example of the degree of variation of science instruction across the province.

The majority of interviewees mentioned that the science instructional equipment and material resources available in their schools were outdated, not in working condition, or not kept in a centralized location for easy access. These resources are required for teachers to be able to facilitate the development of science process skills. The inadequate availability of these resources is not unique to Ontario, however, American studies have also identified teachers' reported need for science equipment (Appleton, 2002; Appleton & Kindt, 2002; Smith et al., 2013), which has been found to impact teachers' willingness and desire to teach science (Appleton, 2002). Again, if the resources available for teachers to teach science are unequally distributed across schools throughout the province some students are inevitably at a disadvantage.

Lastly, the time and effort required to collect and prepare the resources for many experiment-based lessons were also identified by interviewees as a limitation to science instruction. Several interviewees explained that they have to go out and purchase the consumable materials they need outside of working hours and bill them back to their schools. One interviewee expressed that the forethought and preparation required to regularly implement experiment-based activities deters teachers from wanting to do them—especially with all the other tasks needing to be completed during each school day. Milner, Sondergeld, Demir, Johnson, and Czerniak (2012) reported that teachers consider the preparation of these materials and equipment required for science instruction to be a disadvantage and a deterrent to implement inquiry models of instruction, especially because there is no additional time provided for teachers to set up before or clean up after their science instruction.

Administrative and Peer Supports for Science Instruction

Providing teachers with the necessary human supports to implement reform-based practices into their instruction is pivotal for science education reform (Powell & Anderson, 2002); however, many of these supports for science instruction are rarely experienced by teachers (Milner et al., 2012). Administrative (i.e., principals and vice principals) and peer supports have the potential to provide school-based support systems that encourage the transformation of teachers' instructional practices.

About 60% of the survey participants from this study reported that they were either unsure or disagreed that their administration supports their attendance at science PD. Additionally, only about half of the survey participants reported feeling supported by their administration to use scientific-inquiry strategies within their practice. Interestingly, all six interviewees reported feeling supported by their administration, but only two felt that their administrators specifically supported them in their science instruction. Supovitz and Turner (2000) as well as Milner et al. (2012) found that on average, teachers who feel supported by their administration to learn and implement reform-based approaches in science were more likely to do so than teachers who do not feel this type of support.

Crawford (2007) states that when teachers have the opportunity to plan instruction together they fulfill the roles of co-planners, co-learners, coaches, and facilitators. This dynamic allows teachers to share ideas, questions, and concerns while learning about and implementing reform-based teaching strategies. Structured time for collaboration has been deemed to play an influence on teachers' motivation and thus the quality of their instruction (Solis, Vaughn, Swanson, & Mcculley, 2012). Unfortunately, over 65% of survey participants reported that they rarely or never have the opportunity to co-plan for science instruction. A perceived lack of support and accountability for instructional progress results in teachers being less likely to independently engage in the learning required to implement reform-based practices (Milner et al., 2012).

Instructional Strategies

The survey asked teachers to report the frequency that they facilitate various types of science instructional strategies. The majority of survey participants reported that their science instruction primarily consists of direct instruction involving science content or the facilitation of large group discussions about science concepts. Just under half of the survey participants reported frequently implementing project-based learning and about 40% said that they regularly focus on the development of science process skills. According to the TIMSS *Ontario Report* (EQAO, 2011), only 22% of Grade 8 students are taught by teachers who focus on the process of investigations in at least half of their science lessons.

Survey participants also emphasized their belief that incorporating student interest into their science instruction is highly important. The TIMSS *Ontario Report* (2011) reported that only 29% of Grade 8 students in Ontario indicate liking science. Ainley and Ainley (2011) found that student interest and enjoyment of science is highly correlated and that students who are found to enjoy science have a greater belief that they can be successful in future science-related tasks. Making connections to the real world during science instruction was also noted to be of importance to many survey participants. Hodson (2011) explains that students' understanding of the interrelations between science, technology, and society should be a priority in science education as this understanding promotes social responsibility within a democratic society.

The results from this study indicate that only about a quarter of surveyed teachers are regularly facilitating SI activities during science instruction. To add to this, when survey participants were asked to define SI, only 35% of the responses fit within Banchi and Bell's (2008) model of SI. These results suggest that many teachers do not actually understand the basic theoretical underpinnings of SI, and how to employ it in the classroom. Anderson (2002) mentions that one of the foundational issues with inquiry strategies is that "inquiry" means so many things to different people. Research suggests that teachers may avoid SI instruction because this teaching method is perceived as unstructured and unpredictable compared to more traditional Socratic teaching methods (Thomson & Gregory, 2013). Additionally, without necessary and effective PD, teachers are unlikely to implement new strategies that they did not experience as students themselves (Marbach-Ad & McGinnis, 2008).

Conclusion

The findings from this study indicate that elementary science is not an educational priority in Ontario. This conclusion is based on a number of findings that indicate that many teachers in Ontario do not receive adequate preparation, support, or resources to meet student needs through science education. More specifically, many teachers are not prepared with sufficient content knowledge to teach all the *Science and Technology* strands and topics. For certain, many teachers (approximately 50%) do not believe they are prepared to teach science upon completion of their teacher education program. Additionally, very little effective science PD is being offered throughout the careers of practicing teachers. While survey participants reported having a more positive attitude toward teaching science than expected, 40% of survey participants still reported themselves as not feeling sufficiently capable to teach science. Inadequate time, poor availability of science resources and equipment, and a lack of instructional support make the teaching of science through student-directed approaches challenging. Lastly, the overarching emphasis on language and mathematics in Ontario is evidently undermining the importance and necessity of quality science education in elementary schools—despite the fact that survey participants did not view the current emphasis on language and mathematics as distracting from science education *writ large*.

Science education holds the enormous responsibility of bringing students toward a greater awareness of the intimately complex relationship among natural and human-made systems, scientific and technological advancements, and the values that propagate the direction and influence of these developments (Hodson, 2003). Failing to engage Ontarian students in an education that heightens their awareness to the impact that science and technology have on global and local issues is a decision that reinforces the status quo—a decision that negates the capabilities of future generations to do better than we did.

Implications for Future Research

The findings from this study contribute to the small amount of research focused on elementary science education in Ontario, but also to the field of science education at large. The results from this research lead to many more questions surrounding the current state of Grades 4 to 8 science education in Ontario. First and foremost, it would be beneficial to extend the collection of survey participant data. An increased number of participants would allow for more detailed inferential statistics to be performed and for more relationships among variables to be identified. Attaining a larger sample size from the total population of J/I teachers in Ontario would allow for a more accurate interpretation of the current state of Grades 4 to 8 science education.

The results from this study indicate that having a B.Sc. degree significantly influences teachers' attitudes, including feelings of capabilities and the degree to which science instruction is a personal priority. Future research needs to be conducted on the relationship between academic background experiences and teacher attitudes to determine the undergraduate requirements that best prepare elementary teachers to teach science.

Only about half of the 65% of survey participants who completed a science teaching methods course believe that this course adequately prepared them to teach science. Preservice courses have been found to impact preservice teachers' conceptions about teaching and learning science (van Driel et al., 1998). For many teachers, science teaching methods courses may be the primary opportunity for the development of science instructional strategies and a foundational science PCK due to the shortage of science PD throughout teachers' careers. An examination of science teaching methods courses being taught across Ontario in teacher education programs needs to be completed. Recognizing that the science methods course is not standardized across the province, teacher education research could specifically look to identify the instructional strategies and course expectations that best prepare teacher candidates to teach science. The findings from this type of study could have a significant impact on preservice teachers’ science teaching practices and science self-efficacy with the extension of Ontario teacher education program to a 2-year duration (OCT, 2014).

Little information about the process that teachers go through to plan their science lessons was gathered throughout this research. Knowing how teachers plan their science instruction for Ontario science lessons could provide more specific information regarding the use of their background science knowledge, PCK, instructional priorities, and the use of resources. Follow-up action research could involve the researcher working with an interviewee from each of the self-reported capability levels represented in the interviewee group (i.e., capable, very capable, and specialist) to discuss instructional planning, to observe science lessons, and to debrief the process (Fazio & Melville, 2008). This study would provide additional insight into how various factors (e.g., academic and professional experiences, resources, supports, and time allotment for science) influence the science instruction of those with varying reported levels of capability in greater detail.

Lastly, the interviewees express their concern for the success of science education due to the educational prioritization of language and mathematics. Future research could compare the specific qualities of science education between Ontario and the jurisdictions identified by TIMSS and PISA to have statistically greater student achievement in elementary science. This information could provide insight into how to better prepare teachers to teach science, what types of instructional strategies support student learning and student attitudes, and how to effectively make science an educational priority.

Recommendations for the Future of Elementary Science Education

A multi-stakeholder forum is needed to ensure that STEM industries, the Ontario Ministry of Education, and respective school boards are all receiving the same information regarding the necessary qualities of science education to support students' future career opportunities. At this point a unanimous consensus needs to be achieved regarding the next steps for Ontario elementary science education. I believe that the educational priorities of the Ontario Ministry of Education, the Ontario College of Teachers, school boards, and teachers need to be adjusted in recognition of the environmental crises, evolving societal needs, and unpredictable career realities that upcoming generations will continue to face.

Content knowledge is noted by many educational researchers as a prerequisite to developing science PCK (Appleton, 2007; Bulunuz et al., 2010; van Driel et al., 1998). It would be unreasonable to expect that every elementary teacher be required to have a B.Sc. However, expecting elementary teacher candidates to have some content knowledge across the subjects that correspond to the *Science and Technology* curriculum topics they will be teaching, seems practical. The requirement of an increased minimum of science course requirements could be regulated by the Ontario universities who offer concurrent education programs and teacher education programs. Re-evaluating the entry requirements for teacher education could ensure that even generalist teachers graduate with a basic foundation of science content knowledge.

Having completed several science courses would not provide an equal advantage to someone who has a complete B.Sc., however, it would provide many more students with teachers who would have some background content knowledge in science. All preservice teachers should also be provided with the opportunity to have experience with a variety of science instructional strategies throughout their science methods courses. These applicable learning opportunities would support the development of teachers' science teacher self-efficacy and PCK.

For science education to meet the needs of Ontario students the government needs to do its part by acknowledging and proclaiming science as an educational priority, supporting teachers' with the appropriate PD, and by providing funding for required resources. While adjustments in funding can take time, teachers can also take initiative to connect with local high schools to borrow science equipment (e.g., microscopes, measuring equipment). Alternatively, efforts to raise money within schools for science equipment would not only support science instruction, but would promote the importance of quality science education.

Adequate time needs to be provided for science instruction within the instructional timetable. Studies demonstrate that there is a statistically significant positive correlation with instructional time and student achievement (Blank, 2013; Lavy, 2010). Teachers should not feel that they have to skip teaching entire science units due to insufficient instructional time. Currently language and mathematics are allotted the greatest amount of instructional time for elementary students across the province. While language and mathematics have great importance to our students' lives, science also needs sufficient representation in the instructional schedule.

Both the provincial *Science and Technology* curriculum and the national *Common Framework* document address the fast-paced evolution of scientific and technological information that influences human life and the environment—yet neither document has recently been revised. Curriculum reform is one method through which the importance of science and technology could be publically portrayed. By declaring science as an educational priority and by providing adequate professional and instructional supports, teachers will be more able to meet the needs of younger generations. Instructional adjustments that support teachers' science PCK and student learning will result in a greater understanding of the implications of the evolving scientific and technological knowledge on society. Importantly, through these efforts, students will develop a greater awareness of the opportunities to be involved in the progression of these evolving fields.

Science needs to be acknowledged and presented to students as an educational priority. The results of this type of educational reform do not, however, occur without the reform of teaching practice. Feldman (2000) argues that a primary catalyst for change is teachers' discontent with the results of their current practice. Discontent alongside a realization that new practices and ideologies meet the needs of the students' more effectively may be the most influential factor in getting teachers to consider and apply reform-based practices (Saka, 2013). School boards and supporting educational organizations (e.g., STAO, Let's Talk Science, Smarter Science, etc.) also need to be called into action to better support the PD of their teachers.

Final Words

Revolutionizing science education in these ways is a formidable undertaking. It is unlikely that this type of reform will happen quickly, or even prior to immediate needs being identified. The efforts of teacher education need to support new teachers in becoming more critically aware of their own educational practices and the influence that their educational practices have on their students' future. The Ontario Ministry of Education and the Ontario College of Teachers need to actively support practicing teachers by providing adequate PD, appropriate funding for science teaching materials, and explicit recommendations for the allotment of science instructional time. It is difficult to know where to apply our greatest reform efforts in the cycle of ineffective teaching and learning in science; however, we need to believe that no effort is wasted.

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Appendix A

Survey Questions

Q.1: What is your gender?
a) Female
b) Male
c) Other
d) Prefer not to specify

Q.2: What is your age?

____

Q.3: What school board are you a part of?

____

Q.4: Which of the following degrees or diplomas do you hold? (Check ALL that apply)

BA or equivalent	❑
BSc or equivalent	❑
BEd or equivalent (e.g., at least 1 year of teacher training)	❑
MEd	❑
Other master's degree	❑
PhD or equivalent	❑
Other degree or diploma	❑
No degree or diploma	❑

Q.5: Not including this school year, how many years of full-time teaching experience do you have?
a) Less than 2 years
b) 2 to 5 years
c) 5 to 10 years
d) 11 to 15 years
e) 16 to 20 years
f) 20 – 29 years
g) 30+ years Additional comment section

Q.6: For each of the following areas, please indicate the number of courses you have taken in your undergraduate degree (1 course being the equivalent to a half year course (approx. 36 hours of instruction)):

		0 courses	**1 Course**	**Between 2-4 courses**	**5 or more courses**
a)	Interdisciplinary science (addressed content from multiple science subjects)	❑1	❑2	❑3	❑4
b)	Biology/life science	❑1	❑2	❑3	❑4
c)	Chemistry	❑1	❑2	❑3	❑4
d)	Physics	❑1	❑2	❑3	❑4
e)	Earth/space science	❑1	❑2	❑3	❑4
f)	Environmental science	❑1	❑2	❑3	❑4
g)	Engineering	❑1	❑2	❑3	❑4
h)	Mathematics	❑1	❑2	❑3	❑4

Q.7: In your teacher education program, did you complete a course focused on elementary science teaching methods?
a) Yes
b) No
c) Uncertain

Q.8: If you answered yes to the previous question, would you agree that this course (or other related courses completed in your teacher training) adequately prepared you to teach science?
a) Strongly Agree
b) Agree
c) Uncertain
d) Disagree
e) Strong Disagree

Q.9: In the past 5 years, how much time have you spent participating in professional development experiences related to science education? (i.e., 5 hours = 1 day)
a) 0 – 2.5 hours
b) 2.5 hours – 10 hours
c) 11 hours – 20 hours

d) 21 hours – 40 hours
e) 41 or more hours

Q.10: If you have attended a science-related professional development workshop in the past five years, would you agree that your experience in the workshop(s) has had a positive influence on your science instruction?
a) Strongly Agree
b) Agree
c) Uncertain
d) Disagree
e) Strong Disagree

Q.11: Would you agree that you feel supported or encouraged by the administration at your school to attend science-related professional development workshops?
a) Strongly Agree
b) Agree
c) Uncertain
d) Disagree
e) Strong Disagree

Q.12: If you had more opportunities, would you want to attend professional development workshops related to science education?
a) Yes
b) Maybe
c) No
d) Uncertain

Q.13: You teach science:
a) only for my homeroom class
b) on rotary (i.e., to multiple classes)
c) Other

If you selected "other" please explain:

Q.14: For this school year, approximately what percentage of your total teaching schedule is for science?
a) Less than 20%
b) 20% - 39%

c) 40% to 69%
d) 70% or more

Q.15: What is the average number of students in the science classes you teach this year? (Total class size even if multigrade)
a) Fewer than 15 students
b) 15-19 students
c) 20-24 students
d) 25 to 29 students
e) 30 or more students

Q.16: For which grade levels do you teach science?
____

Q.17: Do you currently teach any split grade science classes?
a) Yes
b) No
If yes, please list the split leveled grades you teach:_______________

Q.18: Measuring in weeks, how much time in the school year does your class have science? (There are typically 40 weeks in each school year)
a) Less than half of the weeks in a school year
b) Half of the weeks in a school year (i.e., every other week or on a half-cycle rotation)
c) Most weeks in the school year
d) Every week, with very few exceptions

Q.19: In an average week (5 day cycle) that science is taught, how many minutes per week does your class spend on science instruction?
a) Zero – 50min
b) 51 – 100 min
c) 101 – 150 min
d) 151 – 200 min
e) 201 +

Q.20: On average over a month, how much time from your scheduled science instruction time would you estimate is lost because of class cancellations, irregular disruptions, or make-up time for work in other subjects?
a) Between 0 – 10 min
b) Between 11 – 20 min

c) Between 21 – 30 min
d) Between 31 – 40 min
e) 40 min +

Q.21: Which of the following statements best describes your own comfort level in teaching science?
a) I consider myself a specialist in this area and prefer to teach mainly in this area
b) I consider myself very capable of teaching science and enjoy teaching this subject
c) I consider myself capable of teaching science, but would prefer to teach other subjects
d) I am not particularly comfortable with science, but teach it when necessary
e) I will teach science only as a last resort

Section 2: Teaching Strategies

Q.22: To what degree do you integrate science with or into any other subject areas?
a) Never
b) Rarely
c) Sometimes
d) Often
e) Always

Q.23: In your science classes, how prepared do you feel to do each of the following in your science instruction?

		Not adequately prepared	**Somewhat prepared**	**Adequately prepared**	**Well Prepared**	**Very well prepared**
a)	Plan instruction so students at different levels of achievement can increase their understanding of the ideas targeted in each activity	❑1	❑2	❑3	❑4	❑5
b)	Teach science to students who have identified	❑1	❑2	❑3	❑4	❑5

	learning challenges					
c)	Teach science to English-language learners	❑1	❑2	❑3	❑4	❑5
d)	Provide enrichment experiences for gifted students	❑1	❑2	❑3	❑4	❑5
e)	Encourage students' interest in science and/or engineering	❑1	❑2	❑3	❑4	❑5
f)	Manage classroom discipline during activities	❑1	❑2	❑3	❑4	❑5

Q.24: When planning science lessons, to what extent do you use…

		Never	**Rarely once a month**	**A few times a month**	**A few times a week**	**Almost every class**
a)	Your own previously prepared lessons?	❑1	❑2	❑3	❑4	❑5
b)	Materials prepared by other teachers?	❑1	❑2	❑3	❑4	❑5
c)	Student textbooks?	❑1	❑2	❑3	❑4	❑5
d)	Other textbooks or resource books?	❑1	❑2	❑3	❑4	❑5
e)	Teacher guides or teacher editions of textbooks?	❑1	❑2	❑3	❑4	❑5
f)	Provincial/territorial curriculum documents?	❑1	❑2	❑3	❑4	❑5
g)	Internet or other computer-based sources?	❑1	❑2	❑3	❑4	❑5

h)	Media-generated materials?	❑1	❑2	❑3	❑4	❑5
i)	Other sources?	❑1	❑2	❑3	❑4	❑5

Q.25: How often do you do each of the following in your science instruction?

		Never	**Rarely (i.e., a few times a year)**	**Sometimes (i.e., once or twice a month)**	**Often (i.e., once or twice a week)**	**All or in almost all science classes**
a)	Explain science ideas to the whole class	❑1	❑2	❑3	❑4	❑5
b)	Engage in whole class discussions	❑1	❑2	❑3	❑4	❑5
c)	Use demonstrations to get students interested in a concept					
d)	Have students read from a science textbook, module, or other science-related material in class	❑1	❑2	❑3	❑4	❑5
e)	Have students memorize science vocabulary and/or facts	❑1	❑2	❑3	❑4	❑5
f)	Engage the class in project-based	❑1	❑2	❑3	❑4	❑5

	learning activities					
g)	Learning science process skills (for example, observing, measuring)	❑1	❑2	❑3	❑4	❑5
h)	Have students represent and/or analyze data using table, graphs, or charts	❑1	❑2	❑3	❑4	❑5
i)	Learning about real-life applications of science	❑1	❑2	❑3	❑4	❑5
j)	Have students attend a science-related field trip	❑1	❑2	❑3	❑4	❑5
h)	Have in-school science-related field trips	❑1	❑2	❑3	❑4	❑5
i)	Have students participate in science fairs	❑1	❑2	❑3	❑4	❑5

Q.26: To what extent do the following limit or restrict how you teach your science class?

		Not at all	**A little**	**Quite a lot**	**A great deal**
a)	The range of student abilities in the class	❑1	❑2	❑3	❑4
b)	The range of difficulties in	❑1	❑2	❑3	❑4

	students' backgrounds (e.g., economic, language)				
c)	The presence of students with special needs (e.g., mental or emotional disorders, physical disabilities)	❑1	❑2	❑3	❑4
d)	Uninterested students	❑1	❑2	❑3	❑4
e)	Disruptive students	❑1	❑2	❑3	❑4
f)	Pressure from parents	❑1	❑2	❑3	❑4
g)	Shortage of computer hardware or software	❑1	❑2	❑3	❑4
h)	Shortage of materials or equipment	❑1	❑2	❑3	❑4
i)	Inadequate physical facilities	❑1	❑2	❑3	❑4
j)	Large class size	❑1	❑2	❑3	❑4
k)	Concerns with personal safety or the safety of students	❑1	❑2	❑3	❑4
l)	Inadequate resource material for lesson planning	❑1	❑2	❑3	❑4
m)	External examinations or standardized tests	❑1	❑2	❑3	❑4
n)	Limits in my own background on the subject	❑1	❑2	❑3	❑4
o)	Inadequate curriculum design	❑1	❑2	❑3	❑4

Q.27: How do you define scientific inquiry in the context of students learning science?

Q.28: How often do you incorporate these strategies into your Science instruction?

		Never	Rarely (i.e., a few times a year)	Sometimes (i.e., once or twice a month)	Often (i.e., once or twice a week)	All or in almost all science classes
a)	Students confirm a principle with expected results are already known	❑1	❑2	❑3	❑4	❑5
b)	Teacher provides students with questions to investigate through given procedure	❑1	❑2	❑3	❑4	❑5
c)	Teacher provides students with questions to investigate in their own way	❑1	❑2	❑3	❑4	❑5
d)	Students develop their own questions to investigate	❑1	❑2	❑3	❑4	❑5
e)	Students conduct independent research	❑1	❑2	❑3	❑4	❑5
f)	Having students make connections between theirexperim	❑1	❑2	❑3	❑4	❑5

	ent results and published material					
g)	Having students communicate their findings in multiple ways (e.g., presentation, report, poster board)	❑1	❑2	❑3	❑4	❑5

Q.29: How often do you use these tasks for assessment in your science classes?

		Never	**Rarely**	**Sometimes**	**Often**	**Frequently**
a)	Tests and/or quizzes	❑1	❑2	❑3	❑4	❑5
b)	Performance tasks (e.g., develop a model or present a demonstration)	❑1	❑2	❑3	❑4	❑5
c)	Lab reports	❑1	❑2	❑3	❑4	❑5
d)	Written reports (e.g., essay-like)	❑1	❑2	❑3	❑4	❑5
e)	Participation	❑1	❑2	❑3	❑4	❑5
f)	Presentations	❑1	❑2	❑3	❑4	❑5
g)	Formative assessments (e.g., self-evaluations, reflections)	❑1	❑2	❑3	❑4	❑5
h)	Worksheets	❑1	❑2	❑3	❑4	❑5

Q.30: If you were to consider a 100-minute block of science instruction, about how much time is spent on the following:

		0-20 min	21-40 min	41-60 min	61-80 min	81-100 min
a)	Non-instructional activities (e.g., attendance taking, interruption)					
b)	Whole class activities (e.g., lectures, explanations, discussions)					
c)	Small group work					
d)	Independent work (e.g., making notes, reading the textbook or other material)					
e)	Test or quiz writing					

Section 3: Availability of Support Resources

Q.31: Which best describes the availability of each of the following resources for small group (4-5 students) work?

		Do not have one per group available	At least one per group available upon request or in another room	At least one per group located in your classroom
a)	Personal computers, including laptops	❑1	❑2	❑3
b)	Handheld devices (e.g., Tablets, iPads, smartphones)	❑1	❑2	❑3
c)	Internet access	❑1	❑2	❑3
d)	Virtual learning resources for science	❑1	❑2	❑3
e)	Calculators	❑1	❑2	❑3
f)	Probes for collecting data (e.g., motion sensors, temperature probes)	❑1	❑2	❑3
g)	Microscopes and slides	❑1	❑2	❑3
h)	Classroom response system or "clickers" (i.e., handheld devices	❑1	❑2	❑3

for electronic student
response)

Q.32: Do you have the opportunity to co-plan your science instruction with other teachers?

a) Always
b) Frequently
c) Sometimes
d) Rarely
e) Never

Q.33: Do you feel supported or encouraged by the administration head at your school to implement strategies like inquiry activities in your science instruction?

a) Yes
b) Sometimes
c) Rarely
d) Never

Q.34: How comfortable do you feel incorporating technology such as computers, netbooks, and tablets into your science classes?

a) Very comfortable
b) Somewhat comfortable
c) Slightly comfortable
d) Not comfortable at all
e) No answer

Section 4: Feelings toward Teaching Science

Q.35: Please respond to these statements based on personal feelings or beliefs.

		Strongly Disagree	**Disagree**	**Neutral**	**Agree**	**Strongly Agree**
a)	I enjoy teaching science.	❑1	❑2	❑3	❑4	❑5
b)	The opportunity to teach science excites me.	❑1	❑2	❑3	❑4	❑5
c)	I feel confident teaching science.	❑1	❑2	❑3	❑4	❑5
d)	I am familiar with the content outlined in the Ontario Science & Technology curriculum for the grades that I teach.	❑1	❑2	❑3	❑4	❑5

	Science instruction is a priority to me.	❑1	❑2	❑3	❑4	❑5

Q.36: How comfortable do you feel with each of the Ontario Science & Technology unit strands?

		Not at all	**Very little**	**Somewhat**	**To a good extent**	**To a great extent**
a)	Understanding Life Systems	❑1	❑2	❑3	❑4	❑5
b)	Understanding Structures and Mechanisms	❑1	❑2	❑3	❑4	❑5
c)	Understanding Matter and Energy	❑1	❑2	❑3	❑4	❑5
d)	Understanding Earth and Space Systems	❑1	❑2	❑3	❑4	❑5

Q.37: Would you agree that The Ontario Curriculum Grades 1-8: Science & Technology (2007) document suggests an educational standard that will meet the needs of students?
a) Strongly Agree
b) Agree
c) Uncertain
d) Disagree
e) Strongly Disagree

Please explain.

Q.38: Does the connection between subject content knowledge and standardized testing influence how you prioritize science education? (e.g., EQAO)
a) Yes
b) Somewhat

c) Uncertain
d) No
e) Strongly Disagree

Q.39: Do you believe that science instruction is important for:

		Strongly Disagree	**Disagree**	**Uncertain**	**Agree**	**Strong Agree**
a)	Students' academic lives	❑1	❑2	❑3	❑4	❑5
b)	Students' personal lives	❑1	❑2	❑3	❑4	❑5
c)	The developmen t of future citizens	❑1	❑2	❑3	❑4	❑5

Q.40: Would you be willing to participate in a follow-up interview?
a) Yes
b) No

Appendix B

Interview Questions

Date:______________________

Interviewee's Name:_____________________________

What school district do you work for?:_____________________________

Interview Questions:

1. Teaching education background? Where? When?
2. How many years have you been teaching?
3. Please describe your academic background in relation to science education.
4. What do you enjoy about teaching science?
5. What do you find to be the most challenging about teaching science?
6. How confident do you feel teaching science? Could you elaborate?
7. What types of science-related professional development workshops have you attended?
   a. Have you felt that these professional development opportunities have benefitted your science instruction?
   b. What types of science-related professional development workshops would offer the best support for science teachers?
8. How much time is allotted for science instruction in your academic cycle?
   a. Do you believe this is enough time?
   b. Is your classroom timetable flexible enough to allow for extra science class time if needed?
   c. Do you ever allow time to be taken away from science class time?
      i. Why or why not?
9. Do you believe that science education is a priority within Ontario? Why or why not?
10. Do you believe your students enjoy science? Explain.
11. Do you believe that the current Science & Technology curriculum sets a standard that encourages students to engage with science in their everyday lives and see potential for themselves in science, technology, engineering, & mathematics (STEM) fields? Explain.
12. Describe a typical science lesson in your classroom.
13. How do you define scientific literacy?
14. What does science education reform mean to you? Please explain.
15. How do you define inquiry?

16. How do you incorporate scientific inquiry activities in your science class(s)?
17. What types of equipment and material resources are available to you as a science teacher?
   a. If you requested additional funding for science supplies how likely are you to get it?
   b. What resources have proven to be most effective for your science instruction?
   c. What additional resources would you like to have?
18. How would you describe the support you receive from your fellow teachers with regard to teaching science?
19. How would you describe the support you receive from your administration with regard to teaching science?
20. How would you like to see science instruction or the curriculum improved?
21. Do you have any additional comments that we haven't addressed regarding science education in J/I classes?